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USSR Report

SPACE

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USSR REPORT

SPACE

CONTENTS

SPACE ENGINEERING

SPACE APPLICATIONS

MANNED MISSION HIGHLIGHTS

TASS REPORTS PROGRAM FOR 'SALYUT-7' FULLY COMPLETED

Moscow PRAVDA in Russian 2 Mar 85 p 2

[TASS Report: "In Automatic Mode. On the Flight of the 'Salyut-7' Orbital Scientific Station"]

[Text] Flight Control Center, 1 March. The "Salyut-7" scientific station has been functioning in near-earth orbit for more than 34 months.

During this time three main expeditions have worked on the station for periods of 211, 150 and 237 days. In addition, there have been four visiting expeditions, including two international ones with cosmonauts from France and India. For the first time a female cosmonaut, S. Ye. Savitskaya, performed work in open space.

A number of complex repair and maintenance operations were performed both inside the "Salyut-7" station and in open space. A significant amount of research and experientation was carried out in the interests of science and the national economy.

The data obtained are being processed by institutes of the USSR Academy of Sciences.

In view of the fact that the planned program of work on the "Salyut-7" station has been fulfilled completely, at the present time the station has been deactivated and is continuing its flight in automatic mode.

CSO: 1866/78-P

COSMONAUT SAVITSKAYA SAYS MANY WOMEN IN COSMONAUT TRAINING

Vilnius KOMSOMOL'SKAYA PRAVDA in Russian 22 Jan 85 p 1

[Interview by V. Fartyshev]

[Abstract] The article is an interview with cosmonaut Svetlana Yevgen'yevna
Savitskaya in connection with the upcoming 12th World Festival of Young
People and Students in Moscow. Savitskaya is a member of the Soviet prepara-
tory committee for this festival.

Savitskaya comments on welding and biotechnology experiments in which she
took part during her second mission on board the orbiting station "Salyut-7"
and she responds to another question about the goals of U.S. and Soviet space
research.

Asked about future flights by women in space, she replied: "The number of
women in the cosmonaut contingent is fairly large, and they represent the
most diverse specialties. I am sure that flights by these women will take
place. Doubts about the possibility or the need of having women work in
space have now been dispelled once and for all. I am also sure that the volume
of operations performed in open space will increase from mission to mission."

FTD/SNAP
CSO: 1866/79

SPACE SCIENCES

ACADEMICIAN ZUYEV NOTES PLANS FOR LASERS ON SPACECRAFT FOR ATMOSPHERIC RESEARCH

Moscow SOVETSKAYA ROSSIYA in Russian 29 Jan 85 p 1

[Article by V. Dolmatov, correspondent]

[Abstract] The article is an interview with academician Vladimir Yevseyevich Zuyev, founder and director of the Institute of Atmospheric Optics in Tomsk, on the occasion of his 60th birthday and his receiving of the order of Lenin.

A preface to the interview notes that Zuyev has devoted his whole life to spectroscopy research. In addition to his institute post, he serves as chairman of the presidium of the Tomsk affiliate of the Siberian Branch of the USSR Academy of Sciences. He is an honorary member of the American Optical Society.

Asked what he considers his foremost accomplishments, Zuyev cited studies of atmospheric optics, and the creation of unique laser complexes. Asked about the efforts that his institute's staff devotes to applied science and whether this does not detract from the basic research obligation of an academy institute, Zuyev replied he is firmly convinced that the director of any institute has a duty to work actively toward practical applications of scientific advances. He noted that his institute earns 10 million rubles annually, which represents as much as 75 percent of its budget, from contract research for industry. At the same time, he said it makes a contribution to advancing theory, noting that four doctoral dissertations were defended and six more were submitted for defense in 1984. No conflict is seen between theory and practice, he said, explaining that part of the staff works on theoretical developments alone, others check them experimentally, and a third group develops models of new technology. Finally, the institute has a special design bureau where test prototypes are perfected for use in industry. Asked about former students of his who have become leading scientists, Zuyev named Yuriy Semenovich Maskushkin, president of Tomsk University, and Mikhail Vsevolodovich Kabanov, director of the Siberian Physical-Technical Institute.

In conclusion, Zuyev was asked about his institute's R&D plans. He replied: "The plans are beyond reckoning! We expect a great deal from laser probing of the atmosphere directly from spacecraft. Weather forecasting will be revolutionized when we succeed in obtaining routinely needed data on the conditions of the atmosphere at all latitudes, longitudes and altitudes

simultaneously. Short-range forecasts will become highly accurate, and long-range ones more reliable. Another task--routine probing of pollution of the atmosphere and of the seas and oceans from space--will be accomplished at the same time..."

FTD/SNAP
CSO: 1866/79

SATELLITE RESEARCH ON SOLAR FLARES

Leningrad LENINGRADSKAYA PRAVDA in Russian 27 Jan 85 p 4

[Interview by Zh. Manilova]

[Abstract] The article is an interview with Professor Grant Yegorovich
Kocharov, head of the astrophysics department of the USSR Academy of
Sciences' Physical-Technical Institute imeni Ioffe. Kocharov comments on
methods which are being used to study the sun's energy and on recent findings
in solar physics.

Particular attention is devoted to spacecraft-aided studies which scientists
of the astrophysics department have been doing of the origin and nature of
solar flares. These studies aimed to ascertain the mechanism by which the
energy of the sun's magnetic fields is converted into the energy of
accelerated elementary particles during flares, Kocharov explains. Satellites
were equipped to register all kinds of particles and radiation—protons,
neutrons, electrons, x-rays, gamma quanta, etc.—with high precision.

Kocharov mentions results of these studies, which he says were discussed at a
recent academy conference. It was found, in particular, that light electrons,
heavy protons and nuclei of a number of heavy elements are accelerated not
in succession, as was formerly thought, but simultaneously. In the space of
a second or fractions of a second, these particles are accelerated over
tremendous distances and acquire energies as high as tens of millions of
electron-volts. Kocharov mentions in particular that solar neutrons which
provided extremely fine primary information on energy characteristics of
the solar acceleration mechanism were registered for the first time in history
with the aid of satellite and ground instruments during flares on June 21,
1980, and June 3, 1982. These neutrons were found to have energies as high
as one billion electron-volts. Results of these studies are expected to find
practical use in the improvement of measures for protecting cosmonauts against
radiation hazard.

FTD/SNAP
CSO: 1866/79

UDC 531.38

POSITIONS OF RELATIVE EQUILIBRIUM OF SATELLITE-GYROSTAT

SARYCHEV, V. A. and GUTNIK, S. A.

[Abstract] The motion of a satellite in a central Newtonian force field was
investigated. It is assumed that within the satellite there are statically
and dynamically balanced flywheels rotating at a constant angular velocity
relative to the body of the satellite. If the center of mass of this
satellite-gyrostat moves in a circular orbit its equations of motion are

$$A\dot{p}+(C-B)qr-3\omega_0{}^2(C-B)a_{32}a_{33}=\hbar_2 r-\hbar_3 q,$$

$$B\dot{q}+(A-C)rp-3\omega_0{}^2(A-C)a_{33}a_{31}=\hbar_3 p-\hbar_1 r, \qquad (1)$$

$$C\dot{r}+(B-A)pq-3\omega_0{}^2(B-A)a_{31}a_{32}=\hbar_1 q-\hbar_2 p.$$

Where

$$\hbar_1=\sum_{i=1}^{n}J_i\alpha_i\dot{\varphi}_i, \quad \hbar_2=\sum_{i=1}^{n}J_i\beta_i\dot{\varphi}_i, \quad \hbar_3=\sum_{i=1}^{n}J_i\gamma_i\dot{\varphi}_i \qquad (2)$$

are the projections of the vector of gyrostatic moment onto the main central
axes of inertia of the satellite-gyrostat Ox, Oy, Oz; p, q, r are the pro-
jections of the absolute angular velocity of the satellite-gyrostat onto the
Ox, Oy, Oz axes; A, B, C are the main central moments of inertia of the
satellite-gyrostat; α_i, β_i, γ_i are constant direction cosines of the axis
of symmetry of the i-th flywheel in the coordinate system referenced to the
satellite-gyrostat; $\dot{\varphi}_i$ is the constant angular velocity of the i-th flywheel
relative to the body of the satellite-gyrostat; ω_0 is the angular velocity
of motion of the center of mass of the satellite-gyrostat in circular orbit;
n is the number of flywheels. In this formulation it is shown that in a
general case there are no more than 24 positions of equilibrium in the orbital
coordinate system. An equation is derived which can be used in evaluating
their stability. References 11: 7 Russian, 4 Western.
[167-5303]

UDC 629.015+531.38

INTEGRABLE CASES OF RESTRICTED DOUBLY AVERAGED THREE-BODY PROBLEM

VASHKOV'YAK, M. A.

[Abstract] The doubly averaged variant of the restricted elliptical problem
of three bodies is described by averaged equations in osculating elements
with the perturbing function W. A force function of an elliptical Gaussian
ring is used in describing the influence of a perturbing point of the mass
m_1 which moves relative to a central body S of the mass $m_0 \gg m_1$ in an elliptical
orbit with the semimajor axis a_1 and the eccentricity e_1. With certain
additional assumptions, a system of Lagrangian equations with two integrals
is derived: a = const, W(a, e, i, ω, Ω) = const. However, these integrals
are inadequate for integrating the system of averaged equations in quadratures.
There are some cases when the problem becomes integrable and an analysis makes
it possible to clarify the qualitative characteristics of orbital evolution
of the point P in orbit and to compute the main quantitative characteristics.
Stationary solutions of the averaged problem are of particular interest because
they determine the simplest elliptical orbits, whose mean elements remain
constant in the considered approximation. Integrable cases of the averaged
problem involve additional simplifying assumptions and are usually governed
by symmetry of one type or another. Due to the complexity of the W function
an analytical investigation is possible in some of these cases for limiting
values of the free parameters of the problem. In the case of arbitrary values
of these parameters a qualitative investigation is possible only by use of
numerical methods. Six cases of the integrable problem are examined. A
detailed study is made of one of the special solutions in which the line of
nodes for the orbit of a point of zero mass coincides with the axis of orbital
apsides of a perturbing body and these orbits themselves are orthogonal.
Figures 4; references 8: 7 Russian, 1 Western.
[167-5303]

UDC 521.1

6π-PERIODIC SOLUTIONS OF PLANE RESTRICTED ELLIPTICAL THREE-BODY PROBLEM IN
NEIGHBORHOOD OF LIBRATION POINTS

IKROTOV, A.

[Abstract] A system of equations of motion of the plane restricted elliptical
problem of three bodies is examined

$$\ddot{\xi} - 2\dot{\eta} - \rho\xi = \nu^2\rho\frac{\partial U}{\partial \xi}, \quad \ddot{\eta} + 2\dot{\xi} - \rho\eta = \nu^2\rho\frac{\partial U}{\partial \eta}, \qquad (1)$$

where

$$\rho=(1+\varepsilon\cos v)^{-1}, \quad v^2=p^3(m_0+m_1)^{-1}, \quad U=\frac{m_0}{\gamma(\xi-\xi_0)^2+\eta^2}+\frac{m_1}{\gamma(\xi-\xi_1)^2+\eta^2}$$

$$\xi_0=\frac{-pm_1}{m_0+m_1}, \quad \xi_1=\frac{pm_0}{m_0+m_1},$$

(2)

p, and v are a parameter, eccentricity and the true anomaly of the orbit of relative motion of one of the attracting bodies with the masses m_0 and m_1; $m_0 > m_1$. The dot represents differentiation for the variable v. Equation (1) has five equivalent solutions which correspond to the libration points. An earlier study (V. P. Yevteyev, TR. XI CHTENIY K. E. TSIOLKOVSKOGO, Kaluga, 1977) dealt with the problem of the existence of nontrivial 4π - periodic solutions of (1) written relative to the independent variable E (eccentric anomaly) in the neighborhood of the libration point. It was established that for the existence of nontrivial 4π -periodic solutions with small $\varepsilon > 0$ there must be a correlation between the parameters $\mu = m_1(m_0 + m_1)^{-1}$ and ε in the form $\mu = \mu_0 + \varepsilon\mu_1 + \varepsilon^2\mu_2 +...$ This article examines the existence of 6π -periodic solutions in the neighborhood of the libration points and their approximate construction. It is shown that with a constant value of the ratio of masses μ there is a neighborhood of the triangular libration point at which (1) allows six families of 6π -periodic solutions. The latter are constructed by the method of indeterminate coefficients in the form of series in powers of eccentricity, where the coefficients are determined from the successive approximations equation. Recurrent formulas are derived for constructing the periodic solutions. References: 4 Russian.
[167-5303]

UDC 629.7

STABILITY OF PERIODIC SATELLITE MOTIONS RELATIVE TO CENTER OF MASS IN CIRCULAR ORBIT

SAITBATTALOV, A. A.

[Abstract] Adequate conditions for orbital stability of periodic Poincaré solutions are obtained for most initial values for some class of autonomous Hamiltonian systems with three degrees of freedom in the case of characteristic degeneration. The results are used in investigating the stability of periodic motions of a triaxial satellite with an ellipsoid of inertia close to a sphere in a circular orbit. Four cases are examined. 1) rotation about the Ox-axis; with transit of the satellite through orbital perigee the projection of the kinetic moment onto the orbital plane is collinear to the radius-vector of the center of mass; 2) rotation about the Ox-axis; with transit of the satellite

through orbital perigee the projection of the kinetic moment onto the orbital plane is orthogonal to the radius-vector of the center of mass. It is shown that the investigated periodic Poincaré solutions are stable in three of these cases. Figures 1; references 6: 5 Russian, 1 Western. [167-5303]

UDC 629.782

OPTIMUM ROTATION OF SOLID BODY WITH ONE AXIS OF SYMMETRY

BRANETS, V. N., CHERTOK, M. B. and KAZNACHEYEV, Yu. V.

[Abstract] The method for solving the problem of optimization and formalization of description of the kinematics of rotational motion of a solid body proposed by V. N. Branets and I. P. Shmyglevskiy (PRIMENENIYE KVATERNIONOV V ZADACHAKH ORIYENTATSII TVERDOGO TELA, Moscow, Nauka, 1973) is used in this study to determine the optimum rotation of a solid body with one axis of symmetry. The problem of comtrol of motion of a solid body about its center of mass is examined. The equations of motion are:

$$\dot{\omega}_1 = \frac{I_2 - I_3}{I_1}\omega_2\omega_3 + \frac{M_1}{I_1}, \quad \dot{\omega}_2 = \frac{I_3 - I_1}{I_2}\omega_1\omega_3 + \frac{M_2}{I_2}, \qquad (1)$$

$$\dot{\omega}_3 = \frac{I_1 - I_2}{I_3}\omega_1\omega_2 + \frac{M_3}{I_3},$$

where I_i are the main central moments of inertia, M_i is the projection of the controlling moment, ω_i are the projections of angular velocity onto the axis of the coupled base E, formed by the main central axes of the eppipsoid of inertia ($i = 1, 2, 3$). It is assumed that the control of M is limited by an ellipsoid similar to the ellipsoid of inertia:

$$\frac{M_1^2}{I_1} + \frac{M_2^2}{I_2} + \frac{M_3^2}{I_3} \leq u_0^2. \qquad (2)$$

The formalism of quaternions is used in describing the motion. Motion of the coupled base E relative to the control base I is stipulated by the quaternion Λ. The following kinematic equations are pertinent:

$$2\dot{\lambda}_0 = -\lambda_1\omega_1 - \lambda_2\omega_2 - \lambda_3\omega_3, \quad 2\dot{\lambda}_1 = \lambda_0\omega_1 + \lambda_2\omega_3 - \lambda_3\omega_2,$$

$$2\dot{\lambda}_2 = \lambda_0\omega_2 + \lambda_3\omega_1 - \lambda_1\omega_3, \quad 2\dot{\lambda}_3 = \lambda_0\omega_3 + \lambda_1\omega_2 - \lambda_2\omega_1 \qquad (3)$$

The following boundary conditions are set for the positions of the solid body and its angular velocity:

$$\Lambda(0) = \Lambda_0, \quad \omega(0) = \omega_0, \qquad (4)$$

$$\Lambda(T) = \Lambda_T, \quad \omega(T) = \omega_T. \qquad (5)$$

Problems in which the boundary values $\omega_0 = \omega_T = 0$ and Λ_0 and Λ_T have arbitrary values are of practical importance. The problem is closed by introducing the optimizable functional

$$I = \int_0^T g\,dt. \qquad (6)$$

Then the problem is formulated as follows: it is necessary to transform the solid body from state (4) to state (5), adhering to equations (1) and (3) under the condition that the restriction (2) is imposed on the controlling moment; in this case the functional (6) must b e minimum. The Pontryagin maximum principle is used in solving this problem. The problem can be reduced to solution of a closed system of nine differential equations. Equations are derived for minimizing rotation and a functional having the sense of expenditure of the working medium. References: 2 Russian.
[167-5303]

UDC 629.7

OPTIMUM PARAMETERS OF AEROGYROSCOPIC SATELLITE ORIENTATION SYSTEM

SARYCHEV, V. A., MIRER, S. A. and ZLATOUSTOV, V. A.

[Abstract] The dynamics of a satellite with an aerodynamic stabilizer and two gyroscopes with parallel precessional axes was investigated. The satellite experiences small oscillations about a zero position of equilibrium in an orbital coordinate system in a circular orbit. The motion of the satellite system relative to its center of mass occurs in a Keplerian orbit. These equations can have non-zero stationary solutions (these correspond to an oblique position of the coupled trihedron Oxyz relative to the orbital system OSYZ). The use of aerodynamic moments in the orientation system is admissible only when these moments are restorative relative to the investigated position of equilibrium. Since the center of satellite pressure is on the Ox-axis, this occurs only in an examination of the direct position of equilibrium or at least such an oblique position of equilibrium in which the satellite turns about the banking axis. Optimization procedures were used in obtaining values of the parameters providing a maximum speed of the orientation system with a fixed aerodynamic parameter. With an increase in the dimensionless aerodynamic parameter χ there is also an increase in ξ_{max}, the maximum degree of stability of the linearized system of equations. However, orientation systems with large aerodynamic parameters have the shortcoming that a satellite with large χ experiences great aerodynamic drag and therefore the motion of the center of mass no longer will occur in a Keplerian orbit. With large χ the satellite will be unable to function long in orbit. A system with optimum speed is

usually degenerate; the satellite, for example, is transformed into a plate or rod. The determined dependence of ξ_{max} and the optimum parameters on χ can be used in the stage of preliminary designing of satellite aerogyroscopic orientation systems. Figures 9; references 13: 11 Russian, 2 Western.
[167-5303]

METHOD FOR EVALUATING PERTURBATION IN ALGORITHMS FOR SOLVING NAVIGATIONAL PROBLEMS

CHERNOV, A. A. and YASTREBOV, V.D.

[Abstract] A method is proposed for investigating perturbations in linear algorithms which arise in solution of a number of problems in navigational support of space flights, such as in algorithms for processing trajectory measurements. Solution of various problems in the dynamics of space vehicle flights can be represented in the form $y = F(u)r(v)$, where $F(u)$ is a matrix and $r(v)$ is a vector, dependent on the vector parameters u and v respectively. In each specific problem $F(u)$ and $r(v)$ have a specific sense. In a special case F and r can be dependent on the single vector $u \equiv v$. The purpose of this investigation is the development of a method making it possible to evaluate perturbations δy of the solution vector arising during perturbations of the vector parameters u and v. These perturbations δu and δy can be caused either by rounding-off errors or by inexact computation of the F matrix if the expression $y = F(u)r(v)$ is a result of linearization of the expression $y = \Phi(u, r, v)$ near some control point or inaccuracy in the a priori information used in computing the F matrix. The method is illustrated in an investigation of perturbations of solution of a system of linear equations derived by the least squares method. Referenes: 1 Russian.
[167-5303]

STATISTICAL REGULARIZATION METHODS IN PROBLEM OF NAVIGATIONAL DETERMINATION OF SPACE VEHICLE ORBITS

MAKSHANOV, A. V., MUSAYEV, A. A. and STEPANYUK, O. M.

[Abstract] In the problem of increasing the efficiency in operation of satellite systems many problems related to determination of space vehicle systems can be reduced to solution of the linear regression problem $R = AQ + \xi$, where $R\langle 1:n\rangle$ is the measurement vector, $Q\langle 1:m\rangle$ is the vector of the

of the unknown but fully determinable parameters subject to evaluation. It is important to be able to determine the Q parameters of space vehicle orbits under conditions when traditional methods do not ensure the required accuracy. Such a situation arises if the orbital plane of the space vehicles and navigational artificial earth satellites to be determined, playing the role of orbital radionavigation points, are approximately coplanar, but also in problems involving the approach of space vehicles to one another. These cases can be reduced mathematically to poor conditionality of the $L = A^T PA$ matrix (experimental plan matrix). A number of possibilities exist. The following case is examined: all the eigenvalues $\lambda_1 \leqslant \lambda_2 \leqslant \ldots \leqslant \lambda_m$ of the plan matrix are found, but λ_1 is close to zero, so that the least squares method evluation is computed but is virtually useless because its dispersion is too great and may not tend to zero when $n \longrightarrow \infty$. However, in this case it is possible to use "regularized" versions of the least squares method, replacing the minimizing problem by its different modifications. It is shown that modification of the standard least squares method procedure makes possible a considerable broadening of the region of observability of a "self-determining" flight vehicle. The greatest difficulty in this algorithm is computation of the regularization coefficient k. Figures 2; tables 1; references: 3 Russian.
[167-5303]

OBSERVABILITY IN PROBLEM OF CORRECTION OF INERTIAL NAVIGATION SYSTEMS USING ADDITIONAL INFORMATION FROM ARTIFICIAL EARTH SATELLITE

KALENOVA, V. I. and MOROZOV, V. M.

[Abstract] A study was made of the effectiveness of using combined inertial system being primary, with the satellite information being used as additional information for correcting the inertial system. Although various kinds of additional information can be obtained from navigational artificial earth satellites, the main type is information on range from an object to the artificial earth satellite. Clarification of the possibility of using any kind of additional information for correction of an inertial navigation system essentially involves an analysis of observability of the system with respect to a particular type of additional measurements. The authors examine the observability problem for a system of inertial navigation system error equations in a case when information is available on the range from an object to one satellite moving in a known circular orbit. It is shown that by use of such additional information it is possible to determine all the principal navigational parameters. An algorithm is presented for such purposes. References 10: 9 Russian, 1 Western.
[167-5303]

UDC 581.521

SPECTRAL CHARACTERISTICS OF PROTONS AT LOW AND HIGH ALTITUDES DURING GEOMAGNETIC
STORM OF 29 JULY 1977

KOVTYUKH, A. S., PANASYUK, M. I., SOSNOVETS,E. N. and REYZMAN, S. Ya.

[Abstract] A study was made of the dynamics of spectra of quasitrapped protons
at an altitude ∼ 500 km in the energy range 50-500 keV during the magnetic
storm of 29 July 1977 on the basis of "Cosmos-900" data. These data are
compared with simultaneous spectral measurements made near the equatorial
plane by the ATS-6, GEOS-1 and 1977-007 satellites. On the "Cosmos-900" the
fluxes of quasitrapped protons were measured with a differential proton
spectrometer. It was found that during the pre-midnight and daytime hours
during a substorm there was an increase in the intensity of the fluxes at the
outer L-shells, whereas in the evening sector the greatest increase in the
fluxes was observed in the inner part of the radiation belts at $L = 3-4.5$.
During a substorm the hardness of the spectra increased with all MLT values,
with the hardest spectra being observed in the pre-midnight hours. During the
daytime hours a maximum appears in the proton spectra during a substorm,
whereas during a magnetically quiet time the spectrum of quasitrapped protons
at low altitudes is monotonic. The spectra of protons at different altitudes
are similar in both the nighttime and daytime sectors. The pitch angle dis-
tribution at an altitude ∼500 km in the daytime sector at this time was
anisotropic, whereas in the nighttime sector the proton fluxes were isotropic.
The joint analysis of the spectral characteristics of protons at low and high
altitudes at the time of injection of particles in the outer region of the
radiation belts indicates that the formation of fluxes at low altitudes is due
to the effect of two mechanisms: adiabatic transport of particles and develop-
ment of a strong pitch angle diffusion at low altitudes during interaction
between particles and ion-cyclotron electrostatic waves. Figures 3; references
18: 4 Russian, 14 Western.
[167-5303]

UDC 533.951

EXPERIMENTAL RESEARCH ON IONOSPHERIC DISTURBANCE CAUSED BY CUMULATIVE BARIUM
VAPOR INJECTION

ZHULIN, I. A., MILINEVSKIY, G. P., LOYEVSKIY, A. S., MOYSYA, R. I.,
ROMANOVSKIY, Yu. A., RUZHIN, Yu. Ya. and SKOTAROVSKIY, V.S.

[Abstract] The "Spolokh-2" rocket experiment was carried out in the Volgograd
test range on 29 June 1978 at 2105 LT with a solar zenith angle 98° during

gradual onset of a moderate geomagnetic storm (K_p = 3). The objective of the rocket experiment was study of a cumulative jet of barium vapor and the disturbances arising during decleration of the plasma jet in the ionosphere. A capsule with an injector was separated upward along the rocket axis with a relative velocity of 10 m/sec and was stabilized by additional rotation. The barium jet was injected at an altitude of 155 km at the trajectory apogee of an MR-12 rocket. The distance between the injector and rocket at the time of charge detonation was about 1 km. The barium vapor jet was injected downward in the direction of the rocket nosecone which carried a complex of diagnostic instrumentation. The angle of the direction of injection and the geomagnetic field vector in the injection region was 20°. The capsule carried a total mass of 0.66 kg of metallic barium. In comparison with the injector usually used, this injector had a higher coefficient of transformation of shot energy into jet kinetic energy. The instrumentation carried mass spectrometers for measuring the neutral and ionized components of the jet in the range of masses 40-160 a.m.u. and the neutral and ion makeup of the ionosphere, an ion trap for measuring the total concentration of ions, a Langmuir probe and impedance probe for measuring the concentrations and temperature of the electrons and a Geiger counter for measuring fluxes of electrons with an energy $E > 40$ keV. Surface observations were made with a radar of 22.5 and 33.8 MHz at a point 350 km from the launching point and optically at two points with an image converter and aerial camera located at distances of 30 and 70 km from the launching site. It was possible to register effects associated with shock wave propagation in the ionosphere: the collisionless ionization effect, the phenomenon of "raking together" of plasma, and others. A stimulated leakage of high-energy electrons was discovered; this has the nature of artificial pulsations of electron fluxes. The ionospheric phenomena registered during injection of the jet are satisfactorily explained within the concepts of the "snowplow" theory. It is shown that the stimulated leakages of high-energy electrons can be associated with the excitation of MHD waves in the ionosphere during injection of the jet. Figures 6; references 11: 7 Russian, 4 Western. [167-5303]

SUBSTORMS IN ENERGETIC RADIATION BELT PARTICLES ACCORDING TO DATA FROM 'METEOR' ARTIFICIAL EARTH SATELLITE

GINZBURG, Ye. A. and MALYSHEV, A. B.

[Abstract] Electrons with energies $E_e > 0.15$ and > 0.7 MeV were registered by Geiger counters carried aboard the "Meteor-2" (No 1) satellite in a quasi-circular orbit with a mean altitude of about 900 km. The article examines the mechanisms responsible for substorm variations of fluxes of high-energy electrons near the high-latitude boundary of the geomagnetic trap, with details being given on phenomena observed during the preliminary and explosive phases

of the substorm of 3 March 1976. Particular attention is given to the con-
sequences resulting from the injection of blobs of hot plasma into the "core"
of the magnetosphere. The picture of the substorm at 1019, 1157, 1415-1716
and 1716 UT is discussed in detail. The objective was to answer such questions
as the following. Was there movement of the boundaries toward the equator
before the substorm on the nighttime side and what was the last measured
boundary prior to the explosive phase relative to the undisturbed boundary?
What was the behavior for the daytime boundary? Was there poleward motion of
the nighttime boundary after the explosive phase? How far poleward was the
boundary displaced? Were the fluxes intensified in the quasicapture region
on the daytime side after the substorm? This examination, including answers
to the posed questions, supplemented by data on geomagnetic field variations
and data on auroras, fully confirmed the nature of the main physical mechanism
of variations of structural parameters of the magnetosphere during a substorm.
Figures 3; tables 1; references 9: 5 Russian, 4 Western.
[167-5303]

UDC 550.370

MEASURING ELECTRICAL FIELD FLUCTUATIONS BY LANGMUIR DOUBLE PROBE METHOD

KOREPANOV, V. Ye.

[Abstract] This is essentially a continuation of the author's earlier article
entitled "Evaluating the Error in Measuring Strength of the Permanent
Electrical Field by the Double Langmuir Probe Method" (KOSMICH. ISSLED., Vol 20,
No 5, p 690, 1982) in which it was shown that it is important to measure
electrical field strength in space plasma and a discussion of the components
of the total error in measuring quasistationary electrical fields is presented.
The nature of this total error is now explored in greater depth. The case of
a variable field is considered and the individual components of this error are
taken into account and minimized. The procedures for measuring fluctuations
of the electrical field in space plasma on which such an analysis is based are
described. The different types of errors are examined separately (the total
error consists of such components as plasma noise, influence of satellite hull,
the dynamic error arising with a change in the measured parameter with time
and the dynamic instrument error associated with its inertial properties and
determined by the time constants of its different elements). After presenting
recommendations on how to minimize these errors, a formula is derived which
makes it possible to determine the requirements on the instrumentation and to
evaluate the anticipated measurement error. References 9: 6 Russian, 3 Western.
[167-5303]

MODELING PLASMA MANTLE OF EARTH'S MAGNETOSPHERE

PODGORNYY, I. M., POTANIN, Yu. N. and SEMENOV, I. A.

[Abstract] H. Rosenbauer, et al. (JGR, Vol 80, p 2723, 1975) proposed a
mechanism of formation of the high-latitude boundary layer (mantle) due to the
reflection of charged particles penetrating into the polar cusps from the mirror
points and their simultaneous drift onto the nighttime side in crossed electric
and magnetic fields. The Rosenbauer model was based on a single-frequency
approximation and therefore neglects the possible influence of the plasma flow
in the boundary layers on the strength of the electric field and the nature
of the current in the polar cusp region. The authors in essence sought to
duplicate this postulated mechanism experimentally. The simulation was carried
out using the M-2 apparatus at the Space Research Institute. The model of the
magnetosphere was created with interaction of a super-Alfvén flow of collision-
less hydrogen plasma with a magnetic dipole. The experiment shows that at
least the outer part of the mantle, adjacent to the magnetopause, can be
interpreted as a direct continuation of the boundary plasma layer through the
polar cusp. The boundary layer itself is formed on closed magnetic lines in
the low-latitude region of the daytime magnetopause. A model of filling of the
mantle of the earth's magnetosphere developed in this study can reflect reality
during prolonged existence of a polarization electrical field. It is impossible
to refute the Rosenbauer mechanism entirely and it may be correct for the
inner part of the mantle, but there is strong evidence that the Rosenbauer
model is not applicable to the outer part of the mantle. Figures 3; references
13: 4 Russian, 9 Western.
[167-5303]

PERIODICITY OF VARIATIONS IN GALACTIC COSMIC RAY FLUXES AND SOLAR ACTIVITY
PARAMETERS NEAR TWENTIETH CYCLE MINIMUM

GORCHAKOV, Ye. V., IGNAT'YEV, P. P., OKHLOPKOV, V. P. and SHVIDKOVSKAYA,
T. Ye.

[Abstract] An autocorrelation analysis of Wolf numbers clearly reveals a two-
year periodicity in solar activity during the period 1970-1975. Then, up to
1978, no such periodicity was detected and there was no correlation with
earlier data (probably attributable to the low level of solar activity and the
onset of a new solar activity cycle). Against this background a correlation

analysis was made of the mean monthly fluxes of cosmic rays measured aboard spacecraft, in the stratosphere (at Murmansk) and at the earth's surface (Deep River), as well as Wolf numbers. The cosmic ray data cover the period May 1971-March 1976; the Wolf number data are for the period May 1970-February 1978. The objective was to find a periodicity on the basis of the correlation dependences of two-year intervals of data on cosmic rays and Wolf numbers. An approximately two-year periodicity in the modulation of cosmic rays was discovered (May 1971-April 1973; May 1972-April 1974; May 1973-April 1975; May 1974-March 1976). The manifestation of this perioicity is different for different measurement periods and different energies of galactic cosmic rays. In those cases when there are peaks of the dependence of GCR of different energies on corresponding variations of Wolf numbers with a lage of several months, the lag for particles of lesser energies is usually greater. This means that the region of modulation of particles of lesser energies is greater and is manifested even with monthly averaging of data. A table gives data on the maxima of the correlation coefficients, the lag relative to Wolf numbers and the extent of the modulation region on the assumption of a plasma velocity of 300 km/sec. The tabulated data characterize the dependence of the extent of the modulation region on the energy of GCR particles. Fibures 2; tables 2; references 6: 5 Russian, 1 Western.
[167-5303]

IONIZATION COEFFICIENT FOR ATOMIC COLLISIONS IN METEOR TRAIL

SAIDOV, K. Kh., Tajik State University imeni V. I. Lenin

[Abstract] In DOKL. AN TadzhSSR, Vol 27, No 2, 1984 the author derived a semi-empirical formula for determining the ionization coefficient β for the collision of meteor atoms with atmospheric atoms and molecules: $\beta = 4.70 \cdot 10^{-15} v^2 (1 - E_i/E)$, where E and v are the kinetic energy and velocity of the meteoroid and E_i is the ionization potential of meteor atoms. This formula has now been used for computing β for the mean chemical composition of meteor bodies. Solution of many problems in meteor astronomy, however, require a knowledge of the ionization coefficient for different chemical elements making up meteor matter. The cited formula is used in computing the values of the ionization coefficient for the main components of meteor matter. Computations of β for the usual atoms were made for meteor velocities 10-70 km/sec. The results are given in a table. Special attention was given to atoms with numbers up to $Z = 30$. There is a definite regularity in the behavior of the curves of the dependence of the ionization coefficient on atomic number Z. Curves of the dependence β (Z), constructed for different meteor velocities, duplicate one another in shape but β increases with an increase in velocity and falls in the range 0.0016-0.226. The β (Z) curves show that there is a clear correlation between changes in β and the atomic number Z with transition

from elements of one period to elements of the next period there is a jumplike change of the ionization coefficient, within one period the value of the ionization coefficient gradually decreases with an increase in atomic number Z and with a given velocity for elements with the atomic number $Z > 20$ the β value remains virtually constant. There is a quadratic dependence of β on meteor velocity which is consistent with the direct correlation between ionization efficiency and the kinetic energy of meteor atoms during collisions with atmospheric atoms and molecules. Figures 2; tables 2; references 7: 6 Russian, 1 Western.
[58-5303]

UDC 521.6

ACCURACY IN PREDICTING ORBITAL MOTION OF ARTIFICIAL EARTH SATELLITE

KHOLSHEVNIKOV, K. V., SOKOLOV, L. L., TIMOSHKOVA, Ye. I. and TITOV, V. B.

[Abstract] With any increase in the desired accuracy in predicting the orbital motion of an artificial earth satellite there is an increase in the number and complexity of describing of the perturbing forces. Only relatively recently this problem was not so acute because an error of 10-100 m was deemed acceptable and existing theories were oriented on that accuracy. Today, however, laser systems can ensure a measurement accuracy of 1 m-1 cm. The following perturbing effects must therefore be taken into account: perturbations from geopotential; lunar-solar and planetary perturbations; atmospheric drag; solar and terrestrial radiation pressure; perturbations related to coordinate system, such as precession, nutation, motion of poles, continental drift, etc.; relativistic effects; electromagnetic forces (charged satellite in magnetic field); finite dimensions of artificial satellite; influence of asphericity of artificial satellite on orbital motion; errors in coordinates of tracking station, and others. The most important of these are discussed. With an increase in the desired prediction accuracy the problem therefore becomes increasingly complex and then virtually impossible. The perturbations acquire stochastic properties. It appears that a prediction accuracy of 1 m is attainable (at least in small time intervals for high satellites where atmospheric stochasticity exerts no effect). However, an accuracy of 1 cm is evidently unattainable without invoking fundamentally new ideas. The stochasticity of perturbations must somehow be taken into account. It is not impossible that a guaranteed prediction accuracy of 1 cm in entirely unattainable. Figures 1; references 7: 4 Russian, 3 Western.
[45-5303]

INSTABILITY OF SOLAR WIND NEAR STREAMLINED BODIES

VESELOVSKIY, I. S., Nuclear Physics Institute, Moscow State University

[Abstract] A study was made of the hydrodynamic instability of waves in the
solar wind near planets and comets. It is postulated that the solar wind has
a point of stoppage on a contact surface within which it does not penetrate.
This case approximately corresponds to reality in the case of flow around
some planets and comets. This phenomenon is investigated using a hydrodynamic
model of the soalr wind (not taking into account additional sources of
particles). The flow near such an obstacle is nonuniform and inhomogeneous
and this can give rise to instability. The increment is computed and the
nature of this instability is analyzed. It is demonstrated that the reason
for this instability is inhomogeneity of the velocity field, slowing of the
flow and its shearing. A formula is derived for determining the local
instability increment. This is followed by calculations of the nature of
instability near the point of stoppage in front of and behind the body. A
study of the influence of viscosity revealed that the region of unstable wave
vectors is narrowed under the influence of viscosity. References 15:
7 Russian, 8 Western.
[52-5303]

GEOPHYSICAL RESPONSES OF DYNAMICS OF SOLAR WIND TRANSITION REGION

LOTOVA, N. A. and KOZLOVSKIY, V. D., General Physics Institute, USSR Academy
of Sciences; Applied Geophysics Institute, USSR State Committee on Hydro-
meteorology and Environmental Control

[Abstract] During recent years much new information has been obtained on the
state of the region of formation of the supersonic flow of the solar wind, the
transition region situated at a distance $\sim$10-20 $R_\odot$ from the sun. These
data are used in a study of the responses of solar wind velocity at great
distances from the sun and the K_p index to the temporal dynamics of the
transition region. A comparison of all available data reveals the principal
features of the dynamics of the transition region of circumsolar plasma: the
main geometrical characteristics of the transition region, its inner and outer
boundaries. A particular case is examined for which the transition region
was situated at a distance $\leqslant$ 32$R_\odot$ from the sun. It is shown that there is a
correlation between the geometry of the transition region and the geomagnetic

activity level: the closer the transition region is to the sun, the higher the geomagnetic activity level. The temporal changes in the geometry of the transition region reveal a correlation with solar wind flow at great distances from the sun, with v_{eff} when $R \gg 0.5$ a.u. and with the K_p index. These data may be useful in predicting geomagnetic activity, possibly 6-7 days in advance in comparison with 1-2 days when using routine observations of scintillations in regions remote from the sun. Figures 3; tables 1; references 21: 13 Russian, 8 Western.
[52-5303]

UDC 523.165

VARIATIONS IN INTENSITY OF SECONDARY COSMIC RADIATION OBSERVED ON 10-11 AUGUST 1981

Moscow GEOMAGNETIZM I AERONOMIYA in Russian Vol 24, No 5, Sep-Oct 84 (manuscript received 14 Nov 83) pp 719-722

IYUDIN, A. F., KAPLIN, V. A., KIRILLOV-UGRYUMOV, V. G., KOTOV, Yu. D., SMIRNOV, Yu. V., TYSHKEVICH, V. G. and YUROV, V. N., Moscow Engineering Physics Institute

[Abstract] Quasiperiodic pulsations of the charged and neutral components of secondary cosmic radiation were investigated during 1979-1981 during a series of flights of the "Nataliya-1M" γ-telescope carried aloft on high-altitude balloons. The results of one such flight at latitude 46°N are discussed in detail. The fluxes of different cosmic radiation components were registered with four intensimeters in which information was accumulated for 2 seconds after each triggering of the gamma-telescope. Balloon measurements were made at an altitude of 35 km for 5 hours. The flight was made against the background of a magnetic storm recovery phase. The instrument was oriented to the zenith. The discrete Fourier analysis method was used in detecting quasiperiodic pulsations of cosmic radiation particles. Quasiperiodic pulsations of fluxes of particles with periods 1.1-1.25, 1.4-1.5 and 11.3 minutes were detected. The period 11.3 minutes corresponds to pulsations of the proton component of cosmic radiation with $E_p > 200$ MeV, whereas the periods 1.1-1.5 minutes correspond to the electron component with $E > 15$ MeV. This phenomenon of quasiperiodic pulsations of streams of leaking particles is important both from the point of view of the mechanism of generation and propagation of electromagnetic waves in the plasmasphere and from the point of view of understanding the dynamics of high-energy particles in the inner radiation belt. Figures 3; references 27: 6 Russian, 21 Western.
[52-5303]

DETERMINING EFFECTIVE RATE OF PLASMA HEATING IN OUTER EQUATORIAL IONOSPHERE
USING DATA FROM ISIS-1 AND ISIS-2 SATELLITES

KASHCHENKO, N. M. and NIKITIN, M. A., Kaliningrad State University

[Abstract] Data from the ISIS-1 and ISIS-2 satellites on electron temperature
at a planetary scale at altitudes 1,400 and 3,000 km were given by L. H. Brace,
et al. in J. ATMOS. TERR. PHYS., Vol 43, p 1347, 1981 for periods of high and
low solar activity. This information, which served as the source material
for this study, indicated that in the outer low-latitude ionosphere there are
considerable electron temperature gradients at great altitudes during both
daytime and nighttime. The daytime gradients in the region of closed lines
of force can be explained on the basis of heating of ionospheric electrons by
photoelectrons forming during the photoionization of neutral components of the
lower atmosphere and escaping upward along the lines of force, whereas the
origin of the nighttime electron temperature gradients is associated with the
nonstationary nature of thermal processes, transverse heat transfer and change
in the nature of the longitudinal thermal conductivity of plasma where there
are low electron concentrations. It is these data which are used in finding
the effective rate of heating of ionospheric plasma in the outer ionosphere.
The following additional considerations were taken into account in deriving
the necessary formula: at altitudes greater than 1,000 km the principal
thermal processes for electrons are heat transfer due to thermal conductivity,
heat exchange with ions, heating by suprathermal photoelectrons during the
daytime and possibly transverse heat transfer at nighttime. The effective rate
of plasma heating is very strongly dependent on electron temperature. There-
fore small errors in measuring T_e can correspond to significant errors in deter-
mining k (effective rate of plasma heating). The error in determining k can be
$\sim$100%. The proposed method makes it possible, therefore, to determine k with
an accuracy to a factor of 2. Tables 1; references 6: 2 Russian, 4 Western.
[52-5303]

INFLUENCE OF TROPICAL F REGION IN IONOSPHERE ON PROPAGATION OF SHORT RADIO
WAVES

KOLOMIYTSEV, O. P. and SAVCHENKO, P. P., Institute of Terrestrial Magnetism,
Ionosphere and Radio Wave Propagation, USSR Academy of Sciences; Moscow Physical
Technical Institute

[Abstract] A numerical study was made of tropical ionospheric waveguides in
the presence of stratification of the electron concentration maximum. Under

these conditions a specific form of vertical electorn concentration profile
is formed which to a great extent determines the nature and conditions of
propagation of short radio waves in the low latitudes. The phase trajectories
were computed for a spherically stratified ionosphere. Three approaches for
description of the ionospheric waveguide were used: comparative, temporal,
latitudinal. Examples of computations are given which show that in a wide
spatial-temporal range in the tropical ionosphere there is an additional
ionospheric waveguide in which radio waves can be propagated along ricochetting
trajectories. At identical time there can be three types of phase trajectories
or three types of adjacent channels, each of which is characterized by a
definite working frequency and definite conditions for the propagation of
radio waves in it. The computations presented here give a qualitative
representation of the influence of stratification of the electron concentration
on the formation, dynamids and degeneration of the additional ionospheric wave-
guides in the tropical latitudes. These results are important for further
experimental and theoretical studies of propagation of short radio waves on
long and superlong trajectories passing through the tropical ionosphere.
Figures 5; tables 4; references 17: 7 Russian, 10 Western.
[52-5303]

GLOW OF IONOSPHERIC F-LAYER IN LINE 630 nm DETERMINED FROM PHOTOGRAPHS TAKEN
ABOARD 'SALYUT-6' ORBITAL STATION. INTERPRETATION OF RESULTS

NESMYANOVICH, I. A., IVANOV-KHOLODNYY, G. S. and NIKOL'SKIY, G. M. (deceased),
Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation,
USSR Academy of Sciences

[Abstract] Photographic observations of the second luminescent layer in the
upper atmosphere made from the "Salyut-6" station afforded new possibilities
for studying the ionospheric F-region. It was necessary to determine whether
the registered high intensities agree with data from other surface and space
measurements and to ascertain why this layer was not reliably detected during
other manned flights. An attempt was made to solve these problems using data
published by V. V. Ryumin, et al. (GEOMAGNETIZM I AERONOMIYA, Vol 23, p 533,
1983). These data are also compared with other space and surface measurements.
The "Salyut-6" data were consistent with other measurements and theoretical
computations. Eight frames showing the most typical cases of observations of
the second layer and with minimum image blur were selected for processing.
With an increase in flight altitude from 250 to 350 km the observed surface
brightness at the maximum of the luminescent layer increases by a factor $\sim$ 1.6.
The brightness of the second layer lies near the threshold of visual registry
of radiation and therefore even such an increase can favor detection of the
glow. The dependence of brightness of the second layer on solar depression and

geomagnetic latitude cited in the article by Ryumin, et al. cannot be accepted. The only conclusion that can be drawn is that the maximum brightness of the second layer is observed in the tropical zone and at the near-midnight hours. (This is confirmed by OGO-4 and AE-E data.) Figures 2; tables 1; references 17: 5 Russian, 12 Western.
[52-5303]

MEASUREMENTS OF FLUXES OF HIGH-ENERGY PROTONS AND ELECTRONS BY TWO OPPOSITELY ORIENTED SPECTROMETERS ABOARD 'COSMOS-368' ARTIFICIAL EARTH SATELLITE

BRATOLYUBOVA-TSULUKIDZE, L. S., VOLODICHEV, N. N., NECHAYEV, O. Yu., SAVENKO, I. A., SUSLOV, A. A. and SHAVRIN, P. I., Nuclear Physics Institute, Moscow State University

[Abstract] The "Cosmos-368" AES carried two identical SEZ-1 scintillation-Cherenkov spectrometers, one of which had its axis of maximum response directed to the zenith, whereas the other was oriented to the nadir (aperture angle of each instrument 45°). A similar experiment was carried out on the "Cosmos-208" and "Cosmos-228" satellites, in the first case with the instrument oriented to the nadir, in the second case, oriented to the zenith. The purpose of the new investigation was to check the conclusions drawn on the basis of measurements made with these two satellites. The observations, at altitudes 200-300 km, involved measurements of electrons with $E_e \geqslant 20$ MeV and protons with $E_p \geqslant 100$ MeV, $\gg 500$ MeV. The following facts were confirmed. There is a so-called inverse latitudinal variation of excess radiation in the equatorial region; there are brief variations in the intensity of registered radiation at all latitudes. In addition, it was possible to evaluate the suitability of the L parameter for describing the latitudinal variation of primary and secondary cosmic rays and to determine the upper limits of fluxes of proteons with $E_p \geqslant 100$ and $\gg 500$ MeV in the region of planetary negative magnetic anomalies. There is no significant altitudinal dependence of radiation registered with the SEZ-1 in the range 200-400 km and there was a quite small secular variation of cosmic rays during the years 1968-1970. Figures 1; references: 3 Russian.
[52-5303]

UDC 550.383

BURSTS OF RELATIVISTIC ELECTRONS IN MAGNETOPAUSE AND IN OUTER RADIATION BELT

BEZRODNYKH, I. P., BEREZHKO, Ye. G., MOROZOVA, Ye. I., PISARENKO, N. F,
PLOTNIKOV, I. Ya. and SHAFER, Yu. G., Space Physics Research and Aeronomy
Institute, Yakutsk Affiliate, Siberian Department, USSR Academy of Sciences

[Abstract] Increases in the intensity of relativistic electrons are observed
in the earth's outer radiation belt. A study of the dynamics of these electrons
was made due to the possibility of their generation in the transition region
of the magnetosphere. Information has been collected from simultaneous
observations of fluxes of relativistic electrons in the orbit of a geostationary
satellite and near the magnetopause. During 1977-1979 more than 10 such events
were observed; all were preceded by an increase in solar wind velocity. The
data on increases in the density of relativistic electrons near the magnetopause
and in the outer radiation belt indicate a close interrelationship between
these two phenomena and solar wind velocity. The presence of a layer of shear
flow of plasma near the magnetopause indicates that the origin of relativistic
electrons may be caused by the process of their frictional acceleration in the
layer. The effectiveness of the frictional acceleration process increases with
an increase in solar wind velocity. Electrons, accelerated near the magnetopause,
due to scatterings can enter the region of quasicapture in the tail of the
geomagnetosphere where they experience drift motion across the tail and also a
process of radial diffusion, as a result of which the electrons penetrate into
the radiation belts. The presence of relativistic electrons near the magneto-
pause may be explained by the frictional process of their acceleration in the
layer of shear flow of solar wind plasma adjacent to the magnetopause. The
diffuse penetration of electrons into the inner region of the magnetopause
causes the observed increase in the intensity of relativistic electrons in the
outer radiation belt. Figures 2; references 10: 8 Russian, 2 Western.
[52-5303]

UDC 550.383

CORRELATED FLUCTUATIONS OF CHARGED PARTICLE FLUXES AND MAGNETIC FIELD ACCORDING
TO DATA FROM 'INTERCOSMOS-10' SATELLITE

GLUKHOV, G. A., KRATENKO, Yu. P., KUZNETSOV, S. N. and MINEYEV, Yu. V.,
Nuclear Physics Institute, Moscow State University

[Abstract] Observations by "Intercosmos-19" during the magnetic storm of
3-5 April 1979 revealed streams of protons of solar cosmic rays (SCR) with
energies $E_p \geqslant 0.9$ MeV at latitudes $\Lambda \geqslant 58°$. Considerable magnetic field

variations were registered at the boundary of the SCR streams. Pulsations of quasitrapped streams of protons and electrons were discovered in the region of these variations. In all the analyzed spectra there is a spectral maximum at a period 15-20 sec; in the D-component there is a spectral maximum at a period ~ 3 sec. The nature of these phenomena were investigated using data from simultaneous meausrements of streams of charged particles and the geomagnetic field during transit of the satellite through the auroral zone in the afternoon sector in the recovery phase of the strong magnetic storm of 4 April 1979. An analysis indicated that at a period of 15-20 sec there is a predominance of a magnetosonic mode of the wave and at a period of 2.5-3 sec —an Alfvén wave mode. The period of pulsations of the intensity of electrons with E_e = 0.6-0.9 and 0.9-1.2 MeV indicated that the period of pulsations of the intensity of these electrons is also 15-20 sec, indicating that the period of the pulsations is not dependent on energy. The different possible hypotheses for explaining these pulsations are reviewed. For example, the period 2.5-3 sec is close to the gyrofrequency of ring current protons. Pulsations of streams of protons with $E_p \geq$ 0.9 MeV may be caused by parasitic scattering on cyclotron radiation of ring current protons and violation of the second invariant during resonance interaction with pulsations with a period 12-20 sec. Figures 3; references 10: 7 Russian, 3 Western.
[52-5303]

INTERPLANETARY SCIENCES

TASS UPDATE ON FLIGHTS OF 'VEGA-1' AND 'VEGA-2'

Moscow MOSKOVSKAYA PRAVDA in Russian 1 Mar 85 p 3

[TASS Report]

[Text] Space Telecommunications Center, February 28. The flight of the automatic interplanetary stations "Vega-1" and "Vega-2", which are intended for studies of the planet Venus and Halley's Comet, is now into its third month.

During the time that has elapsed, 67 periods of radio communication have been conducted with the stations. Measurements have been made of parameters of the stations' trajectories of movement, the operation of onboard systems has been monitored, and scientific and telemetry information has been transmitted to Earth during these periods. The "Vega-1" and "Vega-2" stations are continuing to move along paths that are close to the calculated ones.

Measurements of characteristics of galactic and solar cosmic rays, magnetic fields and interplanetary plasma are being made from the stations in the course of their flight along the Earth-to-Venus route.

Signals from radio transmitters installed on the "Vega-1" and "Vega-2" spacecraft were received on January 21 and February 18, for the purpose of preparing for fundamentally new studies of the circulation of Venus' atmosphere with the aid of aerostatic probes. Taking part in the receiving and processing of this information were stations located in Yevpatoriya and Simeiz in the Crimea, near Moscow, and in Goldstone (USA), Joddrell Bank (Great Britain), Canberra (Australia) and Onsala (Sweden)·. Interaction among various links of the ground measurement system was perfected in the course of experiments. Precise determination of the aerostatic probes' locations during their upcoming drift in Venus' atmosphere will be ensured with the aid of this system.

As of February 28, 1985, the stations "Vega-1" and "Vega-2" had reached the distances of 18.7 and 17.8 million kilometers from Earth, respectively.

According to telemetry data, the onboard systems of the stations are functioning normally. Scientific information that is being received from the interplanetary routes is being processed and studied at the USSR Academy of Sciences' Institute of Space Research and at other Soviet and foreign scientific centers which are taking part in the experiment.

FTD/SNAP

CSO: 1866/79

KOVTUNENKO DISCUSSES 'VEGA' PROJECT

[Talk recorded by Irina Yegorova]

[Text] The Vega project is based on an ingenious idea of a consecutive flight first to Venus, and then to Halley's comet. The possibility arose due to the unique position of Venus and the comet near its perihelion, i.e., the point of the maximum approach of the comet's orbit to the Sun. This makes it possible to direct the spacecraft to Halley's comet by means of a gravitational maneuvre in the Venus field of gravity after the spacecraft has flown past the planet.

The cost of such a project, which is not unimportant, is much lower than a separate mission to the comet, since the flight includes simultaneously the exploration of both Venus and Halley's comet.

A rendezvous with Venus will be most unusual. During the planetary entry of the landing modules, balloon probes will be released at a set altitude. The modules themselves will land on the planet's surface. Being in a thermal equilibrium with the environment, the balloon will start drifting in the atmosphere with the wind. A pod containing research equipment will be secured to the balloon by means of a 12-metre line. To ensure reception of the research information transmitted by this equipment to the Earth, two networks of radio telescopes have been set up: a Soviet network coordinated by the Institute of Space Research of the USSR Academy of Sciences, and an international one coordinated by the French National Centre of Space Research. The latter network includes the largest, and medium-size, radio antennae in Europe, Asia, North and South America, Australia and southern Africa.

Balloon probing will make it possible to solve a number of the most important questions which cannot be solved by means of landing systems; the method will be executed for the first time in the history of cosmonautics.

Having accumulated information from their messengers to Venus and upon having transmitted it to the Earth, the stations will continue their journey to Halley's comet where there are problems to be solved.

A flight to the comet will be in many ways much more complicated than other routine flights to planets. At the moment not even the comet's orbit has been determined with a sufficient degree of accuracy. The point is that in the region of its maximum approach to the Sun, the comet is subject to considerable non-gravitational accelerations. This is associated mainly with reactive forces which arise from the powerful evaporation of ice of the cometary nucleus, as a result of which gases flow off its surface almost at a sonic speed. Various jet flows are often observed, sometimes visually.

In order not to miss the comet and fly at a predetermined distance from its nucleus, on the sunlit side, the comet's orbit will be constantly monitored according to the data obtained from ground observations, and the spacecraft trajectory corrected accordingly.

In this respect the West European probe Giotto is in a much better position, since its rendezvous with the comet will occur two days after Vega. Therefore, its orbit will also be corrected by the data received from the Soviet spacecraft.

For Japanese scientists determining the accuracy of the comet's orbit is not so important, since they do not expect to fly past the cometary nucleus closer than 100,000 kilometres.

Despite the fact that the Vega spacecraft have been built on the basis of automatic interplanetary stations of the Venera series which had long since made a good showing, there were many things which had to be invented and designed anew.

A high speed of approach to the comet, nearly 80,000 kolometres per second, has become one of the problems. At such a speed dust medium in the cometary atmosphere is a serious danger. In order to have a chance to "survive," the spacecraft must be protected by a heavy shell which will naturally result in a decrease in mass for research equipment. We have chosen to create lightweight but double-layer protective shells. When a dust particle hits the first shell, it breaks through the latter, and evaporates. The second shell in this case remains undamaged. The probability of hitting the hole made in the first shell by another particle is extremely small. Nevertheless, the most vital areas of the station are protected with a three-layer shell.

In the long run Soviet scientists have succeeded in bringing the payload mass in the Vegas to 120 kilogrammes. In the Giotto probe the payload is 49 kilogrammes 200 grammes, whereas in the Planet-A probe it is only 15 kilogrammes. Accordingly, the Vega craft have wider possibilities to study the comet.

We have rejected the idea of transferring research information to storage, as it is usually done, having gone over to direct transmission of measurement data to the Earth. So, even if the spacecraft at a very short distance to the cometary nucleus is damaged, a considerable part of the data will be received, the rate of data transmission to the Earth attained in the Soviet craft being two times higher than that in the case of Giotto. Incidentally, the information on the frequency of contacts with dust particles, which the Vega craft will transmit, will help West European scientists to decide whether it is worth taking risks and coming too close to the nucleus of the comet.

Joint efforts of the scientists of all the countries involved in the Vega project have resulted in the development of special research equipment which will make it possible to explore the structure of the comet's surface and the nucleus composition, the distribution of gas and dust in its atmosphere and a lot of other things.

Research equipment also incorporates a TV system. It includes two cameras and a microprocessor. The system will produce radio spectrum black-and-white pictures and colour-synthesized images of the central region of the cometary atmosphere.

When flying past the nucleus at a distance of 10,000 kilometres, the spatial resolution of pictures will be equal to 180 metres.

The employment of the microprocessor in the TV system has provided considerable intellectual abilities to the latter, which enables it to get adapted to rapidly changing shooting conditions. In particular, it can forecast the comets' motion, to determine an exposure, and to select a "floating" fragment of the picture round the maximum brightness, i.e., the point of the most probable position of the nucleus. All this enables the TV system to obtain a considerable body of information and transmit it to Earth during a period of flying past the cometary nucleus, which lasts a few minutes.

The employment of the latest materials, technologies and achievements in the field of microelectronics has made it possible to attain a record-low mass of only 31.5 kg for such an intricate system equipped with powerful optics.

The construction of a stabilized platform for focussing optical instruments to study the comet is also unprecedented in the world's practice of instrument making for space research. All the platform's electronic units, electric motors and mechanisms are not airtight and can operate in outer space. For all that the platform, with a mass of little over 80 kg, ensures the same load-carrying capacity. The platform is controlled by the TV system signals.

Apart from the equipment installed on the stabilized platform, a number of research instruments are installed directly on board the Vega stations. They are designed mainly to analyze the chemical composition of the comet and the properties of gas and plasma surrounding the comet.

The research equipment will start to accumulate information first of all two days before approaching the comet, some 14 million kilometres away from it. The second session will take place at a distance of about 7 million kilometres from the nucleus. The third session will be started at the moment of rendezvous.

CSO: 1852/5

29

FRENCH AND WEST GERMAN EQUIPMENT FOR 'VEGA' PROJECT

Frunze SOVETSKAYA KIRGIZIYA in Russian 2 Feb 85 p 4

[Article by L. Kondrashevskiy, correspondent]

[Abstract] The article reports on cooperation between the Special Design
Bureau of the USSR Academy of Sciences' Institute of Space Research and
European organizations in the development of spacecraft instruments for the
international project "Vega" to study the planet Venus and Halley's Comet.

It is reported that representatives from an aeronomy laboratory in Paris and
from the M. Planck Institute and an electronics firm in West Germany recently
visited the special design bureau, which is located in Frunze. Professor
Jacques Blamond, head of the aeronomy laboratory, mentioned that his labora-
tory is taking part in seven experiments connected with the "Vega" project.
He commented on the functions of two instruments, developed jointly with the
Soviet bureau, which are installed on modules that will be released from the
interplanetary stations and descend through Venus' atmosphere. The instru-
ments are an ultraviolet spectrometer and an aerosol recorder. The Soviet
bureau and the West Germans reportedly developed an instrument called PUMA,
which is an acronym of 'dust-impact mass analyzer'. The chemical and isotope
composition of particles surrounding the head of Halley's Comet will be
analyzed with the aid of this instrument.

T. Kurmanaliyev, head of the special design bureau, mentioned that other
equipment for the interplanetary stations was developed by the bureau on a
crash basis. He mentioned a unit for controlling scientific apparatus of the
Venus orbiter, and an instrument which will control various stages of the
landing modules' descent into Venus' atmosphere.

FTD/SNAP
CSO: 1866/79

UDC 523.985.7

ANALYSIS OF SHORT-PERIOD CHANGES IN INTENSITY OF HARD X-RADIATION OF SOLAR FLARES REGISTERED ABOARD 'VENERA-13' AND 'VENERA-14' SPACECRAFT

BOGOVALOV, S. V., IYUDIN, A. F., KOTOV, Yu. D., SHUGAL, Ye. V., DOLIDZE, V. Sh., ZENCHENKO, V. M., VEDRENNE, G., NIEL, M., BARAT, C., SHAMBON, G. and TALON, R., Moscow Engineering Physics Institute, Moscow; Space Research Institute, USSR Academy of Sciences, Moscow; Space Radiations Research Center, Toulouse (France

[Abstract] The article gives information on solar flares obtained using the "Venera-13" and "Venera-14" (which carried "SNEG-2M3" instruments) for the period up to 30 May 1981. The basis for the study was 140 records of solar events with a duration of 16 sec with a resolution of 1/64 sec and with a duration of 64 sec with a resolution of 0.5 sec. Data were processed in two stages. All 140 flare records were first subjected to Fourier analysis. If a reliable peak was discovered in the power spectrum of some event a further analysis of this event was made by a different method. The maximum entropy method was used since it has the best frequency reslution for short records of time series. The results of this analysis (and Hα data) are tabulated. Each event is briefly discussed. The events of 27 and 29 March 1982, for example, corresponded to a region measuring $9.8 \cdot 10^9$ cm. The events evidently occurred in the solar corona. The common source was characterized by quasi-periodic changes in the intensity of hard X-radiation. In addition, the observations revealed certain flares with quasiperiodic changes in the intensity of X-radiation of about 10 seconds. The flux of X-radiation of 3% of the sampled flares varies with a period of about a second. Not a single event with a shorter period was discovered. Figures 4; tables 1; references 13: 2 Russian, 11 Western.
[29-5303]

UDC 523.4

MECHANISM OF FORMATION OF LOW TEMPERATURES IN NIGHTTIME VENUSIAN THERMOSPHERE

GORDIYETS, B. F. and KULIKOV, Yu. N., Physics Institute imeni P. N. Lebedev,
USSR Academy of Sciences, Moscow; Applied Mathematics Institute imeni M. V.
Keldysh, USSR Academy of Sciences, Moscow

[Abstract] Anomalously low temperatures of the Venusian nighttime thermosphere
were discovered but have not been theoretically explained. This temperature
in the neighborhood of the antisolar point decreases with altitude from ~170 K
at 100 km to 100-130 K in the exosphere region at 150-160 km. Such a tempera-
ture profile was not predicted in any theoretical model. The Venusian night-
time thermosphere is not a region with increased temperatures and a positive
vertical temperature gradient, but is in actuality a cryosphere. No efforts
have been made to explain this phenomenon. In this article a mechanism is
proposed for explaining the exceedingly low temperatures of the Venusian
nighttime upper atmosphere: cooling by IR radiation in the rotational band
of H_2O molecules. The phenomenon was quantitatively described using a
theoretical model which in the altitude range 100-170 km in the neighborhood
of the antisolar point made it possible to compute the vertical profiles of
temperature and the CO_2, CO, O and H_2O concentrations. In addition to thermal
conductivity the model also takes into account the following processes:
cooling by IR radiation in the rotational band of H_2O molecules; cooling by
IR radiation in the band 15 μm of CO_2 molecules; cooling by IR radiation in
the rotational band of CO molecules; cooling by IR radiation in the line 63 μm
of atomic oxygen; heating of the lower atmosphere by IR radiation in the band
15 μm; energy transfer by winds. The modeling revealed that the role of CO
is insignificant and H_2O emission begins to exert an influence on the thermal
regime of the thermosphere with a relative content $r^0_{H_2O} > 5 \cdot 10^{-6}$ at 100 km. In

a case $r^0_{H_2O} \approx 3 \cdot 10^{-5}$ the computed exospheric temperature decreases to ~125 K.

This is in agreement with actual measurements. Figures 2; references 14:
5 Russian, 9 Western.
[29-5303]

UDC 621.317:523.43

ORIENTATION AND STRENGTH OF MARTIAN MAGNETIC DIPOLE

DOLGINOV, Sh. Sh., ZHUZGOV, L. N. and SHAROVA, V.A.

[Abstract] Magnetograms obtained by the "Mars-2" satellite, not published
earlier, in combination with "Mars-3" and "Mars-5" data, have yielded important

information concerning the Martian magnetic field making possible clarifica-
tion of the nature of the field on the daytime side of Mars, between the shock
wave front and the planet, on orientation of the dipole and extent of the
Martian magnetosphere on the nighttime side and on the strength of the dipole
magnetic moment. All the measurements of "Mars-2," "Mars-3" and "Mars-5" are
consistent and further clarify earlier findings. The axis of the Martian
magnetic dipole is tilted about 15° to the axis of rotation with the north pole
of the dipole being situated at a longitude of about 270° in the southern
hemisphere. On the daytime side of the planet there is a field belonging to
the planet and rotating tegether with the planet. The region of the character-
istic field occupies an equatorial zone with a width $\lessapprox 70°$. The magnetic
field drifts from the higher latitudes onto the nighttime side. With definite
dipole orientations the drift of the lines of force onto the nighttime side
can reach latitudes $\sim 45°$. On the nighttime side the magnetic tail extends
to distances $\sim 26,000$ km. At a distance $\sim 24,000$ km the diameter of the
tail is $\sim 16,000$ km, which exceeds the diameter of Mars by a factor of 2.3.
According to determinations of the dipole field made by different methods the
magnetic moment is in the range $M_M \approx 1.2-2.4 \cdot 10^{22}$ gauss cm^3. The closeness
of the dipole axis to the axis of rotation suggests that the observed field
is the field of a modern dynamo process. Figures 4; tables 2; references 18:
9 Russian, 9 Western.
[167-5303]

POSSIBLE CONFIGURATION OF MARTIAN MAGNETOSPHERE

SMIRNOV, V. N. and IZRAYLEVICH, I. L.

[Abstract] A new quantitative analysis was made of the results of magnetic
field measurements near Mars for determining its strength. The orientation of
the magnetic moment and the configuration of the Martian magnetosphere are also
discussed. The measurement data used were from "Mars-3" and "Mars-5" satellites.
A very simple model was used in the computations. The field measured within
the interaction region was represented in the form of the sum of the character-
istic dipole field and the external uniform field. It was found that the axis
of the Martian magnetic moment is situated near the planetary axis of rotation.
Dipole polarity is the same as for the earth, but the north magnetic pole is
situated in the southern hemisphere. The configuration of the magnetic field
in the neighborhood of the planet reveals that the planet has a characteristic
degenerate magnetosphere in which, due to the merging of the cusps, there is a
characteristic region which, like "a part in the hair," separates the magnetic
field lines emanating from different poles. An induced magnetic barrier can
exist over this characteristic region on the daytime side of the planet. A
quantitative analysis of the magnetic measurements reveals that an equatorial
orientation of the magnetic dipole, indicated by earlier analyses, is a result

of neglecting of the field of intramagnetospheric currents in the models. The
observed magnetic field geometry agrees poorly with the configuration of the
magnetosphere expected for a near-equatorial positioning of the magnetic axis.
Figures 3; tables 1; references 19: 7 Russian, 12 Western.
[167-5303]

POSSIBLE PERIOD OF JOVIAN ACTIVITY AND POSSIBILITY OF SEASONS

VID'MACHENKO, A. P., STEKLOV, A. F. and MINYAYLO, N. F., Main Astronomical
Observatory, Ukrainian Academy of Sciences, Goloseyevo

[Abstract] A study was made of the factors which might be responsible for the
long- and short-period variations of the physical and photometric properties
of the Jovian atmosphere. The investigation was based on published observa-
tional data for the years 1953-1983 relating to the relative brightness dis-
tribution along the central meridian of the planet. The spectral ranges
considered were 0.51 and 0.37-0.40 μm. During the considered period the
greatest reflectivity variations occurred in the southern and northern tropical
zones (STrZ and NTrZ), which were alternately the brightest details on the
disk. The ratio of brightnesses of these regions $A_j = B_{NTrZ}/B_{STrZ}$ was adopted
as the most graphic index of the activity of processes transpiring in the
planetary atmosphere. It was found that there is a cyclicity in long-period
variations of A_j for the hemispheres with a period of about 12 years. This
is closer to the period of revolution of Jupiter about the sun than to the
solar activity index. Solar activity should exert an influence on the dynamics
of processes in the Jovian atmosphere uniformly over the entire planet, but
in actuality there is an alternate brightness increase, first in one hemisphere
and then in the other, during one period of revolution. The observed periodic
brightness change and intensification of hemispheric activity may indicate a
periodic global restructuring of the entire circulation system, structure of
cloud layers and haze layer above the clouds. At present there are inadequate
data for drawing any certain conclusions concerning the temporal variations
of reflectivity. Figures 2; references 16: 6 Russian, 10 Western.
[20-5303]

LIFE SCIENCES

RESEARCH ON ZERO-GRAVITY BOTANY APPARATUS

Vilnius KOMSOMOL'SKAYA PRAVDA in Russian 2 Feb 85 p 3

[Article by S. Lapenis, secretary of the Lithuanian Academy of Sciences' Communist Youth League committee]

[Text] Not too long ago flights by humans into space were the stuff of dreams for many of the world's scientists. At science's present stage of advancement, they are an everyday event.

The time when entire cities are assembled in space is not far off. Scientists are studying the problem of how to ensure the food supply of people in space.

Science associates of the Institute of Botany's plant physiology laboratory under the direction of academician A. Merkis have conducted an experiment which has no counterpart in world scientific practice. During a long flight of Soviet cosmonauts on board a "Salyut" station, a plant was cultivated which passed through all stages of growth. Scientists of the sector headed by Candidate of Biological Sciences R. Laurinavichyus are studying effects of terrestrial gravity on the spatial orientation of plants and processes of their growth and morphogenesis, and they are developing new experimental apparatus for space stations.

Junior science associate Pal'mira Kenstavichene is working productively in this sector. With the help of engineers of the Vil'nyus affiliate of the Experimental Scientific Research Institute of Metal-Cutting Machine Tools, she has developed a unit for growing plant cultures, controlling their growth and studying their internal processes in zero gravity.

(Two photographs are given showing P. Kenstavichene at a terminal, analyzing the intracellular structure of legumes grown in zero gravity; and a unit called "Fiton-2", in which plants are grown on board "Salyut" orbiting stations.)

FTD/SNAP
CSO: 1866/79

35

SPACE ENGINEERING

SPACE POWER PLANTS

[Text] Chapter 4. Solar Photoelectric Space Power Plants

Photoelectric Converters. A semiconducting photoelectric converter (FEP) is a
device in which the energy of solar radiation is converted directly into elec-
trical energy. The operating principle of an FEP is based on the interaction
of solar light with a crystal semiconductor, in the process of which the
photons produce free electrons--carriers of an electrical charge--in the
crystal. Areas with a strong electrical field that are created specially under
the effect of the so-called p-n junction trap the freed electrons and divide
them in such a fashion that a current and corresponding electrical power appear
in the load circuit.

Let us now examine this process in somewhat more detail, although with signif-
icant simplifications. Let us begin with a discussion of the absorption of
light in metals and pure semiconductors (Figure 8). When a flow of photons
strikes the surface of a metal, part of the photons are reflected and the re-
maining part is absorbed by the metal. The energy in the second group of pho-
tons increases the amplitude of the lattice's oscillations and the speed of
the free electrons' chaotic movement. If a photon's energy level is quite
high, it may prove to be sufficient to dislodge an electron from the metal by
imparting to it energy that is equal to or greater than the given metal's work
function. This is an extrinsic photoeffect. If the photon's energy is lower,
in the final account it is all used to heat the metal.

A different picture is seen when a flow of photons acts on a semiconductor.
In contrast to metals, if crystalline semiconductors in pure form (without im-
purities) are not acted upon by any external factors (temperature, an electri-
cal field, luminous radiation and so on), they do not have free electrons that
were dislodged from the atoms of the semiconductor's crystalline lattice.
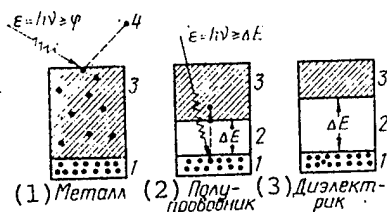
Figure 8. Absorption of light in metals and semiconductors: 1. filled (valence) band; 2. forbidden band; 3. conductivity band; 4. electron.

Key: 1. Metal
2. Semiconductor
3. Dielectric

However, since a semiconducting material is always affected by any temperature (room temperature, most frequently), because of the thermal oscillations a small part of the electrons can take on energy that is sufficient to dislodge them from their atoms. Such electrons become free and can participate in the transfer of electricity.

A semiconductor atom that has lost an electron acquires a positive charge that equals the electron's charge. However, the place in the atom that is not occupied by an electron can be occupied by an electron from an adjacent atom. In connection with this, the first atom becomes neutral and the second one is positively charged. The place in the atom that was freed in connection with the formation of the free electron is equivalent to a positively charged particle called a hole.

The energy that an electron possesses in the state when it is bound with an atom lies within the limits of the filled (valence) band. A free electron's energy level is relatively high and lies in a higher energy band that is known as the conductivity band. Between them lies the forbidden band; that is, the band of those energy values that electrons of a given semiconducting material cannot have in either the bound or the free state. The width of the forbidden band for most semiconductors lies within the limits of 0.1-1.5 eV. For higher forbidden band values than 2.0 eV, we are dealing with dielectrics.

If a photon's energy equals or exceeds the forbidden band's width, one of the electrons is dislodged from its atom and is thrown from the valence band over into the conductivity band.

An increase in the concentration of electrons and holes leads to an increase in a semiconductor's conductivity. The current conductivity that appears in a pure monocrystalline semiconductor under the influence of external factors is called intrinsic conductivity. As the external influences disappear, free electron-hole pairs recombine with each other and the semiconductor's intrinsic conductivity moves toward zero. Ideally pure semiconductors, which would have only a single intrinsic conductivity, do not exist. A semiconductor usually has electron (n-type) or hole (p-type) conductivity.

The type of conductivity is determined by the valency of the semiconductor's atoms and the valency of the atoms of the active impurity that has been introduced into its crystalline lattice. For example, for silicon (Group IV in Mendeleyev's Periodic System) the active impurities are boron, aluminum, gallium, indium and thallium (Group III) or phosphorus, arsenic, antimony and bismuth (Group V). Silicon's crystalline lattice has such a form that every silicon atom that is located on a lattice point is bound with the four closest silicon atoms by so-called covalent or paired-electron bonds.

38

В темноте (1)

На свету (2)

р-область (3) | п-п перекод (4) | п-область (5)

р-область (3) | р п перекод (4) | п-область (5)

Эл. нагрузка (6)

Figure 9. Operating principle of an FEP (the points represent electrons; the circles--holes).

Key:

1. In darkness
2. In light
3. p-area

4. p-n junction
5. n-area
6. Electrical load

Group V elements (donors) introduced at the junction points in silicon's crystalline lattice have covalent bonds between four of their own electrons and four electrons in the adjacent silicon atoms, and the fifth electron can be freed easily. In order to form four covalent bonds, Group III elements (acceptors) that have been introduced on the points of silicon's crystalline lattice attract an electron from one of the adjacent silicon atoms, thereby forming a hole. This atom, in turn, can attract an electron from one of the silicon atoms adjacent to it and so on.

An FEP is a semiconducting photoelement with a back-biased (valve) layer, and its operation is based on the photoeffect that has just been discussed. Thus, an FEP's operating mechanism is as follows (Figure 9). The FEP crystal consists of p- and n-areas that have hole and electron conductivity, respectively. A p-n junction (the back-biased layer) forms between these areas. Its thickness is 10^{-4}-10^{-6} cm.

Since there are more electrons on one side of the p-n junction and more holes on the other, each of these free current carriers will have a tendency to diffuse into that part of the FEP where there is a shortage of them. As a result, in darkness dynamic equilibrium of the charges is established in the p-n junction and two layers of space charges form, it being the case that a negative charge forms on the p-area side, whereas on the n-area side it is positive.

The potential barrier (or the contact difference in potentials) that has been established will prevent further self-diffusion of the electrons and holes

39

through the p-n junction (Figure 9a). Contact difference in potentials U_k is directed from the n-area toward the p-area. The transfer of electrons from the n-area to the p-area requires the expenditure of work $U_k \cdot e$, which is converted into potential energy of the electrons. For this reason, all the energy levels in the p-area are raised relative to those in the n-area by the magnitude of the potential barrier $U_k \cdot e$. In Figure 9, movement upward along the Y-axis corresponds to an increase in the electrons' energy and a decrease in the holes' energy. Thus, the potential barrier is an obstacle for the basic carriers (in the forward direction), but for the nonbasic carriers (in the reverse direction) there is no resistance.

When acted upon by solar light (photons with a certain amount of energy), a semiconductor's atoms are excited and in the crystal--in both the p- and n-areas--there appear additional (excess) electron-hole pairs (Figure 9b). The presence of the potential barrier in the p-n junction causes the additional nonbasic carriers (charges) to divide so that the excess electrons will accumulate in the n-area and the excess holes that did not succeed in recombining before they approached the p-n junction will accumulate in the p-area. In connection with this there will occur partial compensation of the space charge at the p-n junction and the electrical field that has been created by them and is directed against the contact difference in potentials will increase. Taken together, these two factors will result in reduction of the potential barrier.
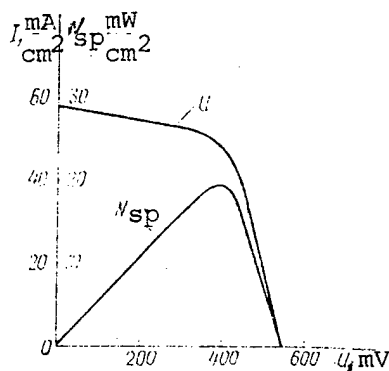
Figure 10. Dependence of voltage and specific power on the density of the FEP's current.

As a result, potential difference U_ϕ, which is essentially a photoelectromotive force, is established between the electrodes. If an external electrical load is connected to the FEP's circuit, an electric current will flow in it. This flow consists of electrons moving from the n-area to the p-area, where they recombine with the holes. The current-voltage characteristic and the power-voltage characteristic of an FEP are depicted in Figure 10, from which it is obvious that in order to draw the maximum electrical power from an FEP, it is necessary to insure that it is operating in a sufficiently narrow band of output voltages (0.35-0.45 V).

Now let us examine briefly the process of manufacturing and designing FEP's. Since the alloying of silicon consists of the purposeful introduction into the semiconductor of donor or acceptor impurities in a concentration of no more than one part per million, the original silicon must be preliminarily purified of impurities until their concentration is no more than one part per billion. Hardly anywhere else are there such high material purity requirements. Any deformation of the semiconductor's crystalline lattice is totally unallowable, because it results in a reduction in the FEP's efficiency. Therefore, it is necessary to cut semiconducting elements out of a single crystal.

40

The carefully purified silicon is remelted with the appropriate amount of alloying additive and p- or n-type silicon is obtained. A silicon monocrystal 6-8 cm in diameter and several tens of centimeters long is then grown from this melt. The growth takes place by gradual crystallization of the material on a crystal core that is fastened to a probe and lowered into the crucible containing the melted silicon (T ≈ 1,420°C). The probe is removed very slowly, bringing with it the column of silicon that has been grown, which has the structure of a monocrystal. The latter is cut into plates 0.3-0.4 mm thick that are 1 x 2, 2 x 2, or 2 x 4 cm in size, and then polished.

The method of thermodiffusion of an additive that is the opposite of the one that has already been introduced into the plate is used to create a p-n junction in the silicon plates that have been obtained. If we have, for example, plates of n-type silicon (with arsenic added), they are placed in a high-temperature chamber and aged at a temperature of about 1,400°C in a medium of vapors of chemical compounds containing elements from Group III (boron, for example). At this temperature, compounds containing boron decompose and liberate the boron, which diffuses into the silicon. By regulating the temperature and duration of the process, it is possible to obtain the desired distribution of boron from the surface into the depths of the plate.

The surface layer becomes p-type silicon. At a depth of several micrometers, where the concentration of the added boron equals that of the added arsenic, a p-n junction is obtained and beyond that there is n-type silicon. Finally, the back side of the plate is metallized over its entire surface, and the front side is in the form of a thin comb that transmits solar light well. Electrical contacts are then soldered to these parts in a fashion such that their resistance is minimal. The metallization can be carried out by spraying, chemical or electrochemical deposition of the metal and so on. FEP's can be connected electrically in sequence or in parallel in order to obtain the required voltage and power. The efficiency of modern FEP's is 10-12 percent.

The temperature, the density of the light flow and the radiation level have the greatest effect on a FEP's functioning. As the temperature increases, an FEP's no-load voltage decreases (about 0.5 percent per 1°C). This results in a decrease in the FEP's output power and efficiency. An abrupt, cyclic change in temperature because of an alternation of light and dark affects an FEP's service life (because of cracking of the electrical contacts). The front side of an FEP is usually covered with special, selective thermal-regulation coatings that provide good absorption of that part of the solar spectrum in which the photons' energy is less than the width of the given semiconductor's forbidden band. The latter is related to the fact that low-energy photons cannot form an electron-hole pair, but only cause heating of the semiconductor.

As the density of the light flow increases there is a linear increase in an FEP's short-circuit current and some increase in the no-load voltage; taken together, these factors result in an increase in the output electrical power. In connection with this, it is always necessary to allow for a possible increase in an FEP's temperature that, in turn, leads to a decrease in its output power. In order to avoid or alleviate this effect it is necessary to take additional measures to cool the FEP. An increase in the degree of

41

Table 5. Basic FEP Parameters

	Материал ФЭП(1)					
	Кремний(2)	Фосфид индия(3)	Арсенид галлия(4)	Теллурид кадмия(5)	Фосфид галлия(6)	Сульфид кадмия(7)
Ширина запрещенной зоны эВ (8)	1,12	1,27	1,38	1,5	2,24	2,4
КПД, % (9) теоретический(10)	21,7	25	26	27	22	19
достигнутый(11) ($T = 25°$ C)	15	6	18	7	1,0	8
Максимальная рабочая температура, °C(12)	100—150	250—300	300—400	300—400	500—650	500—650

Key:

1. FEP material
2. Silicon
3. Indium phosphide
4. Gallium arsenide
5. Cadmium telluride
6. Gallium phosphide
7. Cadmium sulfide
8. Width of forbidden zone, eV
9. Efficiency, %
10. Theoretical
11. Achieved
12. Maximum operating temperature, °C

illumination of an FEP can be achieved by bringing it closer to the Sun (for example, the flight of a spacecraft to Venus) or by using special devices that concentrate the solar energy on the FEP's surface.

Cosmic radiation (electronic and proton irradiation) causes radiation defects in FEP crystals, as a result of which their output power decreases. The Earth's radiation belts and solar flares affect FEP's particularly strongly. Silcon of very high purity with minimum admixtures of foreign substances is used to increase the radiation stability of FEP's, as well as transparent protective coatings of quartz glass that is 0.15-0.2 mm thick and that, at the same time, act as thermal regulation coatings.

The basic parameters of a number of FEP's are presented in Table 5. Besides silicon FEP's, which are used in most solar KEU's [space power plant] at the present time, the most interest is being shown in FEP's based on gallium arsenide and cadmium sulfide. They have a higher operating temperature than silicon FEP's (FEP's based on gallium arsenide have the highest theoretical and practically achieved efficiency). It is necessary to mention that as the width of a semiconductor's forbidden zone increases, so does the no-load voltage and theoretical efficiency of an FEP based on it. However, when the forbidden zone is more than 1.5 eV wide, the FEP's efficiency begins to drop, since the greater part of the photons cannot form an electron-hole pair. Thus, there is an optimum forbidden zone width (1.4-1.5 eV) for which an FEP's efficiency reaches its maximum possible value.

There is great interest in the creation of so-called film (with a total thickness of 3-5 µm) FEP's based on cadmium sulfide. The technology of their production consists of deposition from a gaseous phase, in sequence, of the rear electrode, the n- and p-layers, the front electrode and the protective coatings. The efficiency of such FEP's reaches 6-7 percent and for mass mechanized and automated production, the cost can be less by a factor of 10-23 than for modern monocrystalline silicon FEP's. If this type of FEP is

produced on a substrate in the form of a strong polyamide film that is 40-50 μm thick, it is possible to obtain SB's [solar battery] with specific power parameters that are significantly better than those of modern SB's based on silicon FEP's. The basic flaw in the present film FEP's based on cadmium sulfide is the significant degradation of their parameters with time.

Solar Batteries. In order to obtain a given power and voltage level, FEP's are connected electrically in series-parallel; in connection with this, they are put together structurally in the form of so-called solar batteries.

The first SB's were made in the form of FEP's glued to a spacecraft's hull. However, their effectiveness was not very great, since only a small part of the FEP's could be turned directly toward the Sun. And although their power levels of several watts could be tolerated, when there was a transition to a need for hundreds or more watts, this situation became intolerable. Therefore, panel SB's began to be built.

A panel SB is a rigid framework (or several frameworks) made of light alloys such as aluminum or beryllium alloys. To the framework is attached, for example, a honeycomb substrate made of an aluminum alloy (the thickness of the load-bearing sheets is 0.12-0.15 mm, with the fillers between them being 4-5 mm thick). A layer of an electric insulator 50-60 μm thick is applied to the substrate and the FEP's are fastened to it with a special glue. The FEP's electrical connections are made by soldering thin silver wire. As the substrate on the framework it is possible to stretch a thin (about 50 μm) polyamide film, to which the FEP's are glued, or a thin capron net, to which the FEP's are attached with the help of special wire loops that are on the rear side of each FEP.

Panel SB's can be coupled rigidly to a spacecraft and oriented on the Sun by orienting the spacecraft, as was done with a manned "Soyuz" ship having two SB's with a useful area of about 9 m^2. As a rule, such SB's are made with an output power of no more than 1 kW. For higher SB output powers, there is usually uni- or biaxial orientation with respect to the spacecraft, which makes it possible to obtain the maximum possible power from the SB's for any spacecraft position in space. Panel SB's are oriented with electric drives that are controlled by signals from special solar sensors. That is how the "Salyut-6" orbital station's KEU, which consists of three SB's with areas of 20 m^2 each, was made.

As the SB's power increases to 10 kW and higher, panel SB's are built as unfolding units, similar to a child's foldout book. This makes it possible to have a rather compact SB package while the spacecraft is being inserted into orbit.

Panel SB's have a specific mass of 5-10 kg/m^2, in connection with which about 40 percent of the mass is the FEP's and the rest is the framework structure. The space factor (the ratio of the area of all the FEP's to the SB's area) is 0.85-0.9 in the best case. Considering the resistance of the conductors between the FEP's, the specific power of an SB based on silicon is 100-120 W/m^2 for a light flow density beyond the limits of the Earth's atmosphere of 1,400
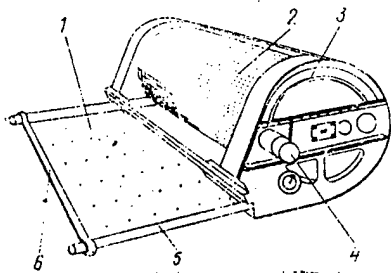
Figure 11. Roll-type SB: 1. fiberglass substrate; 2. FEP's; 3. drum device; 4. electric drive; 5. tubular titanium beam; 6. tie rod.

W/m^2. In connection with this, an SB's efficiency is 7-9 percent, wheras that of the FEP's themselves reaches 10-12 percent.

Another direction for the development of SB designs is roll-type SB's (Figure 11) and flexible SB's (put together like a bellows). Film FEP's were first proposed for use in them. However, since the latter's efficiency increased slowly and the temporal stability of their parameters is still not good enough, the use of solid, monocrystalline FEP's in such SB's began to be discussed.

Assembly and subsequent unfolding of an SB in open space was first done in 1983, by the crew of the Soviet "Salyut-7" orbital station. This amounted to the installation of two supplementary SB's for the purpose of increasing the power of the station's KEU, which was based on SB's. Part of the equipment (the winch, cables, places where the cosmonauts could attach themselves and so on) was installed on the station's hull when it was still on the ground. The cosmonauts went into open space twice, each time removing a container from the transfer compartment of the "Cosmos-1443" satellite ship. This container held a folded-up supplementary SB, which the cosmonauts carried to the installation area and attached to the station's hull, after which they unfolded the SB.

Satellite Solar Electric Power Plants. Recently there have been more and more active discussions of the question of creating solar electric power plants with capacities of 5-10 GW in geostationary near-Earth orbits (at an altitude of about 36,000 km). Such stations would hang over the same point on the Earth's surface at all times. After an examination of several plans, the concept of a satellite solar electric power plant (SSE) was formulated.

According to this concept, a girder-type, load-bearing SSE design with an area of 5 x 10.5 km^2 and a thickness of 1.5-2.0 km would be made of thermoplast reinforced with carbon fibers. Two possible versions have been proposed: one based on silicon FEP's without concentrators, with a total mass of 51,000 t, and one based on gallium arsenide FEP's with flat concentrators made of foil, which would provide a concentration factor of about 2, and which would have a total mass of 34,100 t.

The electricity generated by the SB's would be transformed into high-frequency radio emissions (2.45 GHz) that would be transmitted to Earth by an antenna about 1 km in diameter, with radiated power in the center and at the edges, respectively, of 22 and 2.4 kW/m^2. This radiated frequency insures its practically unhindered passage through the Earth's atmosphere, in any weather, both at night and during the day. The ground receiving antenna, which would have a rectifying unit, is in the shape of an ellipse with sides 10 and 15 km long. The density of the radiation energy at its center would be 250 W/m^2, and along the edges it would be 24 W/m^2. The efficiency levels assumed for

the FEP's are 18 percent for gallium arsenide and 17 percent for silicon. The system's efficiency as a whole would be 7 percent, in connection with which 5 GW of power would be put into the Earth's power system on a continuous basis.

The efficiency of conversion of the SB's direct current into superhigh-frequency radiation is about 90 percent, and the total efficiency of transmission of the electricity into the ground network is about 70 percent.

After initial assembly in a low, near-Earth orbit, the SSE units are transferred from the low (about 300 km) orbit to the geostationary orbit over a period of 110-120 days, with the help of electric jet engines powered by electricity from the SB's in the units themselves, and final assembly of the SSE takes place. In order to assemble a single SSE in 1 year it will be necessary to launch several hundred launch vehicles that can carry a useful load of about 450 t and to have 2 crews of cosmonaut-assemblers: 600-800 people in the low orbit and 80-100 in geostationary one.

The service life of an SSE is 30 years, with degradation of the FEP's characteristics of no more than 7 percent, whereas at the present time this figure would be about 40 percent. Permanent orientation of the SSE on the Sun would be provided by electric jet engines powered by the SSE itself.

In the opinion of a number of scientists, the SSE technology can be developed in the 1990-2000 period, and beginning in 2010-2020 it will be possible to insert two SSE's, each with a capacity of 5 GW, into geostationary orbits every year. If this happens, it may solve to a significant degree the problem of supplying energy to terrestrial consumers without consuming mineral fuels (oil, coal and gas), without polluting the biosphere with consumption products, and without polluting it thermally, which happens when any thermal electric power plant is in operation.

However, in addition to solving the engineering and technological problems, when creating the SSE it is necessary to evaluate its effect on the environment. This includes an analysis of the effect of microwave radiation on people and animals, a study of the effect of microwave radiation and thermal and material pollution from the operation of the launch vehicles' engines on the upper layers of the atmosphere, and the effect of the electromagnetic radiation and ionization of the atmosphere on radio communications.

Ways of Improving KEU's Based on SB's. The basic directions for the development and improvement of SB-based KEU's are: a) improving the characteristics (efficiency, specific mass, cost, radiation stability and so on) of FEP's; b) improving the designs of SB's, particularly with due consideration for raising their power output to tens and hundreds of kilowatts; c) improving the electric power systems of KEU's in order to insure optimum interaction of the SB's, the electrical buffer and the on-board load for the purpose of maximum utilization of the power generated by the SB's.

We have recently seen the creation of silicon FEP's that are transparent in the infrared band of the solar spectrum; that is, in that part of the spectrum where the photons' energy is lower than the level of silicon's forbidden zone

45

and therefore cannot be converted into electrical energy in an FEP. If such an FEP is mounted on a transparent (lattice or film) substrate, then because of the passage through it of the infrared solar radiation (without generating heat), the FEP's equilibrium temperature will be lower, which means that its efficiency increases. If the FEP is mounted on a nontransparent substrate (such as a metal one), then a reflecting layer is applied to its rear surface that reflects the infrared solar radiation back through the FEP's front surface.

The use of selective etching on the surface of silicon FEP's creates a microrough relief that results in a reduction in the reflection from the silicon from 30-40 percent to 10-15 percent, which also results in an increase in the FEP's efficiency.

The list of such measures can be continued, but the creation of cascade FEP's should be regarded as the basic direction of work done toward achieving a substantial increase in efficiency. Solar radiation first strikes an FEP made of a semiconductor with a large forbidden zone (such as gallium arsenide), thanks to which it has high efficiency in the part of the solar spectrum that we need. Photons with energy levels lower than its forbidden zone do not affect this element, the material of which is essentially transparent for them. Passing through the first cascade, these photons strike a second one that is made of a material with a smaller forbidden zone (such as silicon). Its ability to capture these photons is good, although its efficiency is somewhat lower than that of the first FEP.

Such a combination of two (or more) FEP's makes it possible to obtain a higher total efficiency than for each of them separately. An efficiency level of 28.5 percent has already been achieved for a cascade FEP based on gallium arsenide and silicon. A reduction in optical losses of 25 percent will make it possible to raise the efficiency of this FEP to 30-35 percent. This and other new FEP developments are offering further prospects for increasing their efficiency right up to 50-60 percent.

In addition to the development of film FEP's, active work is being done to reduce the thickness of monocrystalline FEP's from 0.2-0.4 mm to 0.05 mm and the thickness of the protective coatings from 0.15-0.2 mm to 0.05 mm in order to reduce the weight of FEP's.

For the extensive use of SB's in KEU's and--particularly--in SSE's, the cost of modern FEP's ($3,000-5,000/kW, in the estimates of foreign scientists), which is the basic part of an SB's cost, must be reduced by a factor of 10-20. This can be achieved only by the creation of large, completely mechanized and automated enterprises for the production of FEP's.

The power required for solar KEU's will be 25-50 kW in 1985-1990 and 100 kW or more in 1990-2000. At the present time, several plans have been developed for 25-kW solar KEU's based on roller-type and flexible SB's; they are now undergoing experimental development. Design plans for 100- and 1,000-kW KEU's are being developed, as well as plans for a 5-GW SSE.

The methods and technology for manufacturing and assembling girder-type SB designs directly in space are being developed. The specific mass of SB's should be reduced several times in the near future because of the use of new materials and improvements in the technology and designs. Later, the specific mass of SB's should be reduced by a factor of 10 during the creation of experimental SSE's.

The electric power circuitry of a solar KEU should insure optimum joint functioning of the SB's, the electrical buffer and the on-board equipment so that when the degree of illumination and the temperature of the SB's change, in each case the maximum possible SB power is used completely. As the required energy capacity of the electrical buffer increases, it has been proposed that the cadmium-nickel AB's [storage batteries] be replaced by a combination of an EKhG [electrochemical generator] and a unit for water electrolysis or a combination of a flywheel and an electromechanical generator that is rotating on a magnetic suspension. In addition, sodium-sulfur or lithium-sulfur AB's can be used for these purposes.

In view of the substantial increase in the level of KEU power, plans are being made to change from current at 27 V to current at 100-300 V in order to reduce electrical losses in the cable network and to reduce the network's weight.

Chapter 5. KEU's Based on Radioisotope Generators

Radioactive Isotopes. Radioactive isotopes (radioisotopes) have unstable nuclei, the composition and structure of which change with time. What takes place is so-called radioactive decay, which is the spontaneous emission by radioactive nuclei of α- and β-particles and γ-radiation. One of the basic characteristics of the decay process is the half-life period; that is, the time in which half the nuclei decay in a given isotope. During the following half-life period, half the remaining nuclei decay and so on. The decay of radioactive nuclei takes place according to an exponential law.

The basic portion of the energy released as the result of radioactive decay is manifested mainly in the form of the kinetic energy of elementary particles or quanta of electromagnetic energy (or both simultaneously). When the nuclear particles and γ-radiation pass through even the thin layers of the metallic shell surrounding the isotope, their kinetic energy is completely converted into thermal energy that can be used to obtain electrical energy. An important parameter for any radioisotope is its specific thermal capacity (expressed in watts per gram).

For use in radioisotope generators (RIG), the most suitable isotope would be one possessing an extended half-life period and a high thermal capacity; as a rule, however, these values are inversely proportional to each other. The basic requirements for an isotope for RIG's are a long (relative to the RIG's operating life) half-life period, high heat liberation density, a low level of neutron and γ-radiation, high melting and boiling temperatures, low toxicity and chemical activity, the possibility of obtaining the radioisotope in the needed amounts and others. Of the large number of isotopes only a few satisfy this complex of requirements (Table 6) and can, therefore, be used in RIG's for KEU's.

Table 6. Basic Characteristics of Several Isotopes

Изотоп/изотопное топливо (1)	Период полу-распада, годы (2)	Удельное тепловыделе-ние, Вт/г (3)	Температура плавления, °C (4)	Ориентир. стоим., долл/Вт (5)
Плутоний-238/^{238}PuO$_2$ (6)	87,5	0,46/0,46	640/2280	500
Кюрий-242/^{242}Cm$_2$O$_3$ (7)	0,45	120/111	950/2000	20
Кюрий-244/^{244}CCm$_2$O$_3$ (8)	18,4	2,8/2,5	950/1950	50
Полоний-210/^{210}PoCd(9)	0,38	144/82,4	260/1365	100
Прометий-147*/^{147}Pm$_2$O$_3$(10)	2,62	0,32/0,27	1160/2320	250

(11) * В отличие от других рассматриваемых изотопов прометий-147 при распаде испускает преимущественно β- (а не α-) частицы.

Key:

1. Isotope/Isotope fuel
2. Half-life period, yrs
3. Specific heat generation, W/g
4. Melting temperature, °C
5. Approximate cost, dollars/W
6. Plutonium-238/^{238}PuO$_2$
7. Curium-242/^{242}Cm$_2$O$_3$
8. Curium-244/^{244}CCm$_2$O$_3$
9. Polonium-210/^{210}PoCd
10. Promethium-147*/^{147}Pm$_2$O$_3$
11. *In contrast to the other isotopes being discussed, promethium-147 emits primarily β- (and not α-) particles during the decay process.

Isotopes in pure form are rarely used as isotope fuel for RIG's, because in most cases they do not satisfy the complex of requirements listed above. Therefore, chemical compounds based on isotopes are mainly used as isotope fuels. This makes it possible to improve several characteristics of isotope fuel: increase the melting (see Table 6) and boiling temperatures and reduce toxicity and chemical activity. According to the characteristics of isotope fuels for RIG's with a service life of up to several months, the most preferable ones are the short-lived isotopes (with a half-life of less than 6 months) polonium-210 and curium-242, whereas for RIG's with service lives of up to several years they are the long-lived (with a half-life of more than 6 months) plutonium-238 and promethium-147.

The short-lived isotopes polonium-210 and curium-242 are α-emitters, and when fuel based on them is used in an RIG, relatively light radiation shielding is required. Besides this, they have a very high specific heat generation factor, which makes it possible to create compact isotope fuel units. However, the short half-life period makes their use in RIG's more difficult, because if the RIG's operating life is up to several months or when there is a planned operational reserve in the case of a delay in the spacecraft's launch, it is necessary to increase the RIG's initial thermal power. RIG's based on the isotopes polonium-210 and curium-242 have been developed for spacecraft in the United States, although until now such RIG's have found no practical use.

The basic isotope for space RIG's is the long-lived isotope plutonium-238, which has a half-life of 87.5 years. Therefore, when it is used in a RIG with an operating life of even several years, the change in the thermal power is extraordinarily small, which makes it possible to avoid thermal regulation. Plutonium-238 is also an α-emitter, so the use of heavy radiation shielding is

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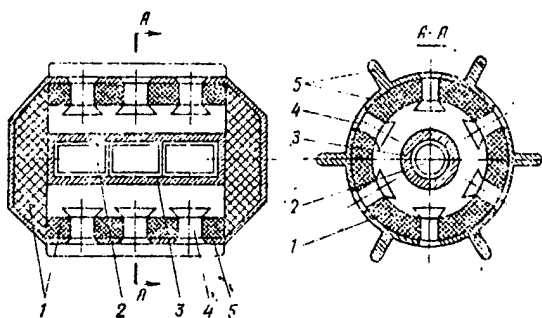
Figure 12. Structural diagram of an RIG: 1. thermal insulation; 2. ampule with isotope; 3. isotope fuel unit; 4. TELP; 5. emitting housing.

not required. In addition, the isotope fuel plutonium dioxide (PuO_2) has a high melting temperature, which makes it possible to create high-temperature isotope fuel units. The shortcomings of this isotope include its low specific heat generation.

Radioisotope Generators. The RIG is a device in which the thermal energy generated as the result of radioactive decay of an isotope is converted into electrical energy by thermoelectric converters (TELP) or thermoemission converters. Thermoemission converters have higher efficiency (15-16 percent) in comparison with TELP's (6-8 percent). Because of technological and design difficulties, however, and despite the fact that experimental models of RIG's with thermoemission converters have been built, until now only RIG's with TELP's have been used in KEU's. In connection with this, we will henceforth confine ourselves to the latter.

An RIG consists of one (or several) isotope fuel units in cylindrical or prismatic form, around which the TELP's are arranged radially (Figure 12). The isotope fuel unit itself is a metal capsule (or capsules) containing the isotope fuel and having an outer ablation coating that provides thermal shielding in case of an emergency aerodynamic descent.

The heat generated during radioactive decay of the isotope in the isotope fuel unit is transmitted by radiation or thermal conduction into heat-receiving "sockets" that enlarge the TELP's heat-receiving surface and passes into their "hot" junctions. The part of the heat that is not transformed into electrical energy is transmitted from the TELP's "cold" junctions through heat conductors into the RIG's housing, which acts as a cooler-emitter, and is discharged into the surrounding space. In order to make the heat discharge surface larger, the RIG's housing is often ribbed.

In order to reduce nonproductive heat leakages, the space between the TELP and the RIG's end faces is filled with highly efficient thermal insulation. In connection with this, the coefficient of utilization of the isotope fuel unit's heat is 0.8-0.9. The TELP is connected electrically inside the RIG in series, and in order to obtain the given voltage and power, it is connected in parallel.

In comparison with the other sources of electricity used on board spacecraft, RIG's have a number of special features that are related to the use of isotope fuel units in them.

When RIG's are installed in a spacecraft, there appears the potential danger of radioactive contamination of the Earth's atmosphere and surface in case of an accident to the launch vehicle that is carrying the spacecraft into a

near-Earth orbit, or an accident to the spacecraft itself, particularly during its return into the dense layers of the atmosphere at the first and even the second cosmic velocities. In order to avoid this danger, the principle of aerodynamic (thermal) shielding of the isotope capsule is used during descent in the atmosphere. In addition, nondispersion of the isotope when the capsule impacts on the Earth's surface and when it stays for a long time (more than 10 half-life periods for the given isotope) on the Earth's surface or in water (an ocean, a lake and so on) is insured.

In an isotope fuel unit based on α-emitters (polonium-210, plutonium-238 and others), helium (an α-particle) is generated during the radioactive decay process, so in order to reduce the pressure inside the isotope capsules some additional free space is left or a special valve for discharging the pressure is installed. Another method that is used is to insert a finely porous filter in the capsule that, while freely passing helium, prevents the escape of the isotope, which in this case is prepared in the shape of special microspheres. All this complicates the design of the isotope fuel units and increases their weight, which in modern RIG's is almost half the generator's total weight.

Another special feature of the use of RIG's in spacecraft is the necessity of using forced elimination systems for the heat that is constantly being generated in an RIG. This is related to the fact that during the prelaunch preparation an RIG is usually placed beneath the spacecraft's fairing, which is discarded after the spacecraft passes through the dense layers of the atmosphere. The proper thermal conditions for an RIG located under a fairing while the spacecraft is still on the ground are provided by forced cooling of its surface with air from outside the ship or by liquid mains that lead into the RIG's housing. This also results in some increase in the spacecraft's mass.

In some spacecraft, an RIG is used not only as a source of electricity, but also as a source of heat, which makes it possible to provide the proper thermal conditions for the spacecraft. In addition, the RIG's heat can also be used to recover the products of the crew's vital activities. This integrated utilization increases the RIG's efficiency as a heat machine. The tapping of heat from the RIG and the feeding of it into the spacecraft's heating elements is accomplished because of the thermal conductivity of the elements in the spacecraft's design or with the help of a gaseous (liquid) heat carrier or heating pipes.

The use of RIG's in spacecraft makes contradictory demands on the RIG's design: for example, insuring the highly reliable and radiation-safe operation of the RIG at all times for the minimum possible mass. Therefore, RIG's are made from special structural materials with low specific weights and high strength. For instance, beryllium and magnesium-thorium alloys are used extensively for the production of RIG housings, including the ribs and end caps. In order to increase the radiative capacity, an RIG's outer surface is covered with special coatings. In order to insure radiation safety, graphite and pyrographite are used extensively as the ablation material in isotope fuel units, and the isotope capsules are multilayered and made of molybdenum, tungsten and other refractory materials.

50

The mission of a spacecraft frequently imposes limitations on an RIG's design and configuration. For example, in a spacecraft that is to be used to measure interplanetary magnetic fields, magnetic materials and electrical circuits are arranged in such a fashion as to reduce the ship's magnetic fields to a minimum. In addition, part of the spacecraft's equipment cannot tolerate a large amount of radioactive irradiation. Therefore, an RIG must have radiation shielding or must be placed at a certain distance from equipment that is sensitive to irradiation. All this sometimes results in the necessity of mounting the RIG on a special bracket that is initially fastened to the spacecraft's hull and then rotated after the dense layers of the atmosphere have been traversed.
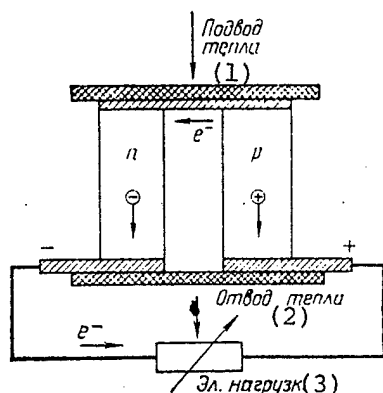
Figure 13. Operating principle of a TELP.
Key: 1. Heat supply
2. Heat discharge
3. Electrical load

Thermoelectric Converters. A semiconducting thermoelectric converter (TELP) is a device in which thermal energy is converted directly into electrical energy. A TELP's operation is based on the utilization of several effects, the main one of which is the Seebeck effect. In the presence of a temperature gradient along an electrical conductor, there is a change in the concentration and average energy of the current carriers and they diffuse toward the area of lower temperature. This process continues until equilibrium is established under the influence of the electric field that arises. The higher the temperature gradient, the greater the degree of diffusion that corresponds to the equilibrium state.

In conductors that are of the same type but are different, such as two different metals, current carriers of a single type--electrons--diffuse. Therefore, at the ends of an open circuit composed of two different metals, a difference in potentials arises that is proportional to the temperature gradient (all other conditions being equal). This difference in potentials is called the thermoelectromotive force. Thermocouples operate according to this principle.

However, an electrical circuit can be composed of two semiconductors of different types--p-type and n-type. In view of the fact that there are different types of conductivity in these semiconductors, holes diffuse to the cold end in one of them, whereas electrons do it in the other. The latter is the cause of an increase in the thermoelectromotive force, since the potentials of the electrical circuit's ends take on different signs. This is also the operating principle of a TELP (Figure 13). When the TELP's electrical circuit is completed by attaching an external load to it, an electric current will pass along the circuit; that is, part of the thermal flow is converted into electrical energy.

A TELP's efficiency and electromotive force depend on the difference between the temperatures of the "hot" and "cold" junctions, as well as the value of

semiconducting material's Q-factor, which is a generalized parameter that
characterizes the semiconductor's quality. The greater the difference in tem-
perature's and the higher the Q-factor, the higher the values of the efficien-
cy, electromotive force and a number of other TELP parameters.

Thus, a high thermoelectric Q-factor for a material is a basic condition for
its use in a TELP. In addition, the material must sufficiently high mechani-
cal strength, stable properties over the course of an extended service life, a
low vapor pressure, and a rather high melting temperature. Since it is prac-
tically impossible to fulfill all these requirements when producing a single
material, the choice of a TELP's material is usually made by taking the spe-
cific conditions of the RIG's operation into consideration.

Different "hot" and "cold" junction temperatures correspond to the high Q-
factor values of various thermoelectric materials. Therefore, thermoelectric
materials are provisionally divided into low-temperature (from -200 to +300°C),
medium-temperature (300-700°C) and high-temperature (700-1,000°C) materials.
Low-temperature thermoelectric materials are not used for space RIG's, because
under the conditions encountered in space, heat can be discharged from the
TELP's "cold" junctions only by radiation, and this would lead to the necessi-
ty of using radiators with intolerably large dimensions and weight for the
RIG's.

The medium-temperature materials used in TELP's for space RIG's are alloys
based on lead telluride or germanium telluride with bismuth and their solid
solutions, whereas the high-temperature ones are alloys based on silicon-
germanium. Such advantages of medium-temperature materials for TELP's as a
high Q-factor or moderate operating temperatures and a relatively low tempera-
ture in the TELP's "hot" junctions make it possible to build RIG's with up to
6-8 percent efficiency, using comparatively low-temperature (800-900°C) iso-
tope fuel units.

Medium-temperature thermoelectric materials have appreciable chemical activity
in the working interval of temperatures and a relatively high vapor pressure
and sublimation rate. Therefore, their use when extended preservation of
their stability is required is possible only in a medium of a neutral gas,
which is most often argon or helium, although this requires that the space oc-
cupied by the TELP be sealed. The greater part of the RIG's for the space-
craft that have been launched into space up until now were based medium-
temperature TELP's. Their service life is 1-5 years.

Thermoelectric materials based on silicon-germanium are the most stable ones
at increased temperatures, have a higher Q-factor (although it is somewhat
lower than that of lead telluride), and can operate in a vacuum and in a medi-
um containing oxygen, without sealing the space occupied by the TELP's. The
basic difficulty encountered when using TELP's based on silicon-germanium in
an RIG is the creation of isotope fuel units capable of operating at high tem-
peratures (1,000-1,200°C). The efficiency of RIG's based on high-temperature
TELP's reaches 4-6 percent. Their service life is 10-12 years.

Segmentation and cascading of the TELP's are used to increase an RIG's effi-
ciency because of expansion of the interval of working temperatures. By
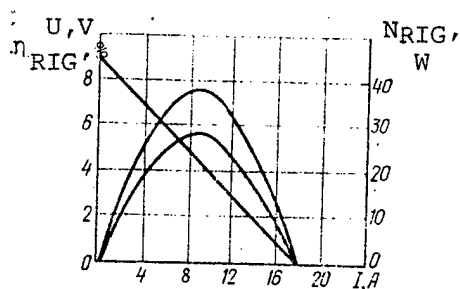
Figure 14. Dependence of RIG voltage, efficiency and power on the current.

segmentation is meant the use in a TELP, in one or both branches, of two (or more) thermoelectric materials that have different working temperature intervals and are connected in series in the electrical and thermal respects. Cascading is the use of several TELP's made from different thermoelectric materials that are connected in series in the thermal respect and in parallel or in series in the electrical respect.

The combination of the best properties of two or more thermoelectric materials in a broad temperature band when each TELP is operating under conditions that are optimal for it makes it possible to create RIG's with up to 10-12 percent efficiency. In the design and technological respects, however, the production of such an RIG is considerably more complicated than that of an RIG based on a single type of TELP.

Since a single TELP provides an electromotive force of no more than tenths of a volt, in order to obtain the needed working voltage in the RIG's output buses it is necessary to have a large number of TELP's connected in series. Series-parallel connection of TELP's is used to obtain the given power and high reliability. Figure 14 shows the dependence of the SNAP-19 RIG's voltage, efficiency and power on the current (it is obvious that the maximum power and efficiency can be obtained only when the current load is completely determined).

In the process of operating an RIG, there is some deterioration of its energy characteristics because of a change in the thermoelectric materials' properties, which leads to a slight increase in the RIG's internal resistance. However, isotope decay is the basic influence on deterioration of an RIG's energy characteristics. A reduction in the isotope fuel units' thermal power leads to a significant drop in the temperature of a TELP's "hot" junctions, as a result of which there is deterioration of the current-voltage characteristics, it being the case that for the working modes, an RIG's electrical power will decrease approximately twice as fast as the thermal power.

Several generators that produce up to 10 W and differ in the design of the housing and the method for attaching the TELP's to the isotope fuel unit's surface were built in the USSR within the framework of the program for the development of the first space RIG's. One of these RIG's was charged with polonium-210 and tested for service life over a period of 2,000 hours. In the other RIG's, electric heaters were installed instead of isotope fuel units; this made it possible to investigate thoroughly the thermal and electrical characteristics and the operational reliability of the TELP's and the RIG as a whole.

After the different variants were examined, an RIG design was chosen in which the isotope fuel unit, in the form of a plane parallelepiped (60 mm wide and long, 13 mm high), was enclosed on both sides by thermoelectric converters.

53

The heat generated by the isotope fuel unit passes through the TELP's and is transferred to the RIG's housing by thermal conductivity, after which it is discharged into the surrounding space by radiation.

The isotope fuel unit was made of stainless steel and had five blind channels to hold the ampules containing the radioactive isotope. The polonium-210 in the nickel ampules was placed inside two stainless steel shells, which were then sealed by welding. The ampules in the shells were placed in the isotope fuel unit's blind channels, which were then closed with threaded stoppers and sealed by heating the heads of the stoppers.

The TELP's were made of a silicon-germanium alloy and attached, in 16 pieces, to the 2 sides of the isotope fuel unit. The generator's housing was made of duraluminum and was divided into two parts in order to insure the necessary thermal contact between the TELP's and the housing and isotope fuel unit. In the housing there was an opening so the space inside could be filled with insulation and the air could be pumped out. This RIG had the following basic characteristics: N_{el} = 10 W; η_{RIG} = 3 percent, weight (without the isotope fuel unit) = 3 kg, height = 128 mm, diameter = 195 mm.

Five "Cosmos"-series artificial Earth satellites were injected into orbit by a single launch vehicle in September 1965. The RIG was installed in one of them as the basic source of electricity. Soon after that, a more powerful RIG was launched into space in another "Cosmos" satellite. Both RIG's completed the planned testing program successfully, in connection with which measures were taken to eliminate completely the possibility of diffusion of the radioactive isotope in the atmosphere and on the Earth's surface.

In the Soviet automatic "Lunokhod" and "Lunokhod-2" vehicles, which reached the Moon in 1970 and 1973, there were isotope fuel units that generated heat for the thermostating of the instrument compartment of each "Lunokhod" during the lunar night (14 terrestrial days).

The KEU of the "Voyager" Spacecraft. The unmanned "Voyager" spacecraft are being used to investigate Jupiter, Saturn, Uranus and Neptune from a fly-by trajectory, utilizing the gravitational forces of these planets. The duration of the flight to Neptune will be 12 years. The design of this spacecraft and its KEU requires a high degree of operational independence, because the time of transmission of a radio signal from Earth to the area of Neptune and back is about 8 hours. This eliminates the possibility of using ground control with operational identification and correction of various faults in the spacecraft and KEU systems.

The maximum electrical power needed for normal operation of the spacecraft's systems, depending on the stage of the flight, is 250-400 W. Three RIG's of the MHW [not further identified] type are the sole source of electricity. At the beginning of the flight they generated 435 W, whereas after 12 years the figure will be 330 W (at 30 V). The necessity of insuring minimum KEU weight and an extraordinarily long service life eliminates the use of buffer storage batteries.

On the whole, an RIG of the MHW type consists of a housing-radiator with TELP's and an isotope fuel unit. The TELP's segmented branches are made of an alloy based on silicon and germanium (80 percent Si and 20 percent Ge) that is alloyed with boron for the p-branch and phosphorus for the n-branch. On the "cold" side in the branches there is an extension piece made of silicon-germanium alloy with a lower silicon content (63.5 percent). The branches are switched back and forth with the help of copper buses. On the "hot" sides of the TELP's there are heat-receiving "sockets"; the 312 TELP's are attached to the housing-radiator by bolts.

The isotope fuel unit is a shell filled with fuel pellets 33 mm in diameter. Each pellet consists of pure plutonium-238 dioxide (PuO_2) and generates about 100 W of heat. The fuel pellets' operating temperature is 1,370°C. The isotope fuel is encased in inner iridium and outer graphite shells that have a series of small openings for the emission of helium. A unit can contain 18-24 fuel pellets and is a load-bearing part of the RIG.

A beryllium alloy is the material that was used for the housing-radiator, heat-discharge ribs and end caps. In order to reduce oxidation of the RIG design's elements under the conditions encountered in the Earth's atmosphere, it was sealed and the inner cavity was filled with an inert gas (xenon). After the spacecraft entered a near-Earth orbit, the RIG was unsealed in order to improve the functioning of the vacuum-screen thermal insulation, which consisted of layers of molybdenum foil alternating with quartz glass film.

The thermal conditions for the sealed container's functioning with the electronic equipment are provided by the heat generated by this equipment, whereas the thermal conditions for the spacecraft systems located outside this sealed container are provided by feeding part of the heat from the RIG via a liquid carrier (or with the help of heating pipes).

The RIG's are interconnected electrically in parallel and form the main direct-current bus. Voltage regulation on the main bus in the 30 V ($\pm$ 10 percent) range is carried out by a common parallel voltage regulator, with the shunting element passing outside the spacecraft. The splitting diodes insulate the RIG from the spacecraft's buses if there is a short circuit in the RIG. Conversion of the direct current at 30 V into alternating current at 50 V is done by a special semiconducting converter.

In order to insure the KEU's survival for 12 years, all its elements have multiple back-ups. A control computer monitors the status of all the basic KEU elements and connects the back-up elements in case of any trouble with them.

As is known, "Voyager-1" and "Voyager-2" were launched on 5 September and 20 August 1977, respectively. After the flight past Jupiter and Saturn, the "Voyager-2" should fly past Uranus on 30 January 1986 and Neptune in 1989.

Ways of Improving KEU's Based on RIG's. The basic area for improving RIG-based KEU's is to improve the parameters of the RIG itself by: a) using improved TELP's and, correspondingly, raising the RIG's efficiency; b) discharging heat from the TELP's rationally, particularly during the initial period of

55

RIG operation; c) using more economical aluminum alloys for the housing and cooling ribs, as well as making a number of structural improvements.

A number of new RIG's are being developed at the present time. The most interesting of them is an RIG based on plutonium-238 or curium-244 that generates 400 W of power (after 5 years of operation). It utilizes TELP's with copper selenide in the p-branch and gadolinium selenide in the n-branch. The "hot" junction's temperature is 800°C; commutation of the TELP's with respect to the "cold" junctions is carried out by copper buses, whereas for the "hot" junctions it is done with tungsten ones. This RIG's efficiency is 10 percent, with a prospective increase to 13 percent. The TELP's are cooled by water-filled copper heating pipes that lead to the isothermal ribs of a radiating cooler.

In conclusion it should be mentioned that in addition to the USSR and the United States, work on KEU's of various types is now being done in the FRG, Japan, France and a number of other countries, it being the case that as space technology develops, this work is being continuously broadened and deepened.

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CONSTRUCTION AND FUNCTIONING OF EXTENDED ORBITAL SYSTEMS

MOSKALENKO, G. M. and ANDREYEV, A. V.

[Abstract] An extended or elongated orbital system is a system whose two
linear dimensions can be neglected in comparison with the third. A quite
general physical model of such a system is an ensemble of several material
points joined into a chain by means of a bond having finite elastic and
dissipative characteristics. A special case of the model would be a cable
system in which an absolutely flexible strand serves as the bond. In the
future such systems may be used as large scientific research or industrial
orbital stations or as space transport vehicles. The concept of regular motion
of an extended system is introduced and stationary and nonstationary cases of
this motion are examined. In each of the indicated cases expressions are
derived which make it possible to compute the mass-geometrical characteristics
of the system. Rules for the construction and transformation of different
systems, one into the other, are formulated for motion of the chain in a
circular orbit with its orientation along the radius vector. For a more
general case of motion the authors separate the problem of system computation
into dynamic and constructive-geometrical parts. General laws of system de-
ployment are established for the considered class of motions. Analytical
formulas are derived for evaluating system parameters in different operation
regimes. Figures 6; tables 1; references 10: 6 Russian, 4 Western.
[167-5303]

ION SENSOR SIGNAL FLUCTUATIONS DURING OPERATION OF SPACECRAFT REACTION ENGINES

LEGOSTAYEV, V. P., NIKOLAYEV, V. D., SAULIN, K. I., SUKHOVOY, M. B. and
UL'YANOV, Ye. G.

[Abstract] The authors present experimental data on the effect of reaction
engines on ion detector signals and empirical rules are formulated which are
applicable in designing ion orientation circuits. The discussion is based on
materials from flights of the "Cosmos-398," "Cosmos-434," "Soyuz," "Progress"
and "Salyut" vehicles. This made it possible to describe the effect of
different engine systems with different thrust and working medium. This is
illustrated in the example of the "Cosmos" satellites which used compressed
air as the working medium. It is shown that the effect of a reaction engine
on the total ion current persists to an altitude of 2,000 km; the amplitude
of the effect is dependent on engine thrust andchanges along the space vehicle
flight trajectory. It was also found that with orbital orientation the ampli-
tude and phase of the engine effect on ion detector signals change along the
flight trajectory; this dependence remains the same for different typyes of
space vehicles, for different thrusts and different types of jet engine fuel.
The gas jets exert a definite influence on the interaction between a space
vehicle and the oncoming flow of ions during operation of the reaction engines
in the orientation system. This results in fluctuations of ion detector signals
indicating, at least, that there is a redistribution of ion concentration along
the front of the oncoming flow. The gas jets exert an influence on ion detector
signals regardless of whether the working medium is compressed air, hydrogen
peroxide or a two-component fuel. The amplitude, duration and phase of
fluctuation of ion detector signals are determined by engine thrust, quantity
of escaping gas and direction of the gas jet. Changes in the amplitude and
phase of the effect of gas jets correlate with :changes in components of the earth's
magnetic field in an orbital coordinate system. Figures 10; tables 1; refer-
ences: 1 Russian.
[167-5303]

HELIOCENTRIC SAIL PROBLEM WITH VARIABLE GRAVITY FIELD REDUCTION

POLYAKHOVA, Ye. N.

[Abstract] Motion in a central heliocentric photogravitational field is
conveniently modeled as motion in a weakened, reduced solar gravity field whose
reduction is a function of the physical parameters of the irradiated body--
the sail effect and reflecting properties. There are three classes of

reflecting bodies for which the solar photogravitational field remains central: sphere; plate-solar sail oriented normal to the light flux; system of mirror-sails, the resultant of the pressure forces on which is rigorously directed along the heliocentric radius-vector of the center of mass of the system. Motion of such bodies in a central photogravitational field is called Tsander motion, after F. A. Tsander, who first examined this problem in the dynamics of space flight on the basis of the restricted photogravitational problem of two bodies. Restricting the examination to elliptical Tsander trajectories corresponding to a predominance of attraction over repulsion and with Tsander unperturbed motion serving as the basis with a constant reduction of solar mass, it is possible to examine perturbed Tsander motion in the presence of some constantly operative perturbing acceleration and take the variability of solar field reduction into account in some problems. With this as a basis, a study was made of the problem of gradual deterioration of a solar sail. A gradual worsening of the optical characteristics of the sail during a flight occurs under the influence of such space factors as a deep vacuum, micrometeorites, corpuscular streams, gamma radiation and high energies. A worsening of the optical characteristics is accompanied by an increase in transparency of the sail film, erosion, turbidity and darkening of material as a result of exposure to high temperatures. Changes in the physical parameters of a solar sail therefore exert a considerable influence on the nature of orbital Tsander motion. Allowance for deterioration of the sail can be extremely important in predicting the motion of a space vehicle with a solar sail in a Tsander elliptical orbit. The calculations presented can be generalized for the case of spiral motion with an arbitrary angle of setting of the sail. Although this study was based on the methods of the theory of perturbations, the equations for the photogravitational problem of two bodies can be integrated in quadratures. References 4: 3 Russian, 1 Western.
[45-5303]

SPACE APPLICATIONS

APPLICATION OF SPACE METHODS IN GEODESY

Moscow KOSMICHESKIYE METODY V GEODEZII (NOVOYE V ZHIZNI, NAUKE, TEKHNIKE: SERIYA
"KOSMONAVTIKA, ASTRONOMIYA") in Russian No 9, Sep 83, pp 43-50, 56-58

[Excerpts from booklet "Space Methods in Geodesy", by Anatoliy Mikhaylovich
Mikisha, candidate of technical sciences, from series "Cosmonautics, Astronomy",
Znaniye, 28,030 copies, 64 pages]

[Excerpts] New Methods of Space Geodesy

The methods of satellite geodesy which we have examined (geometric and dynamic)
have become traditional for geodesy. The development of space geodesy, however,
has continued, particularly in recent years. The perfecting of laser and radio-
technical equipment, the installation of corner reflectors on artificial earth
satellites, the delivery to and placement of such reflectors on the surface
of the Moon and the launch of space vehicles toward distant objects in the So-
lar System--all these and other factors in the rapid development of space tech-
nology and methods for tracking objects in space have increased the possibili-
ties for space geodesy.

Research has been underway since 1974 in the area of satellite altimetry. Las-
er and radio altimeters installed on artificial earth satellites at first pro-
vided information which made it possible to determine the elements of their
orbits with greater precision. With the increase in accuracy, however, it has
become possible to make geodesic use of the altimetric information. The radio
altimeter installed onboard the Geos-3, for example, makes it possible to meas-
ure the distance between the satellite and the surface of the ocean with an
error of 1-3 m. In point of fact, this means that we can define with precision
the shape of the geoidal surface (if the position of the artificial earth sat-
ellite in orbit is well known).

A comparison of the altimetric measurements to profiles of the geoidal surface
constructed using the most up-to-date models of the geopotential confirms the
reliability of this method for determining the shape of the geoidal surface
(true, this can be done only on sections occupied by the world's oceans, but
this area is not inconsiderable--two-thirds of the surface of the globe). It
is anticipated that in the future the accuracy of radio altimeters will be im-
proved to 10 cm. As far as laser altimetry is concerned, theoretically there
is no doubt that it can insure an accuracy of 1 cm. This means that we will
be able to measure the slightest geokinematic effects. We will speak of this
in greater detail in the next section.

The idea of using Doppler methods to measure the radial velocity in a satellite-to-satellite system is of interest. Two versions of this method are being examined. In the first version, the velocity of an artificial earth satellite revolving at a low orbit is measured relative to a geostationary artificial earth satellite. The value of the radial velocity recorded continuously along the flight path of a low-orbiting artificial earth satellite can be calculated numerically, and this provides the values of the acceleration, that is, it directly provides information on the values of the gravitational force acting upon this artificial earth satellite at all points along its suborbital flight path.

At the present time, such measurements are being carried out (the Geos-3, for example, was observed using a stationary artificial earth satellite). The results were, if one can express it in such a way, as expected. The fact of the matter is that the resolution capability of such a method depends to a considerable degree upon the altitude of the low-orbiting artificial earth satellite over the surface of the Earth. The altitude of the Geos-3 was on the order of 840 km, and the data obtained could be interpreted as anomalies in gravitational force averaged according to map projection limits of 7x7°, that is, 800x800 km. In order to obtain resolution in the form of a trapezium of just 2x2° (and one would like to go as far as a trapezium of 1x1°), it would be necessary to reduce the orbit of such an artificial earth satellite to altitudes where it would instantly burn up due to friction in the dense atmospheric layers. In order to reduce atmospheric resistance, it is proposed that a "satellite within a satellite" be built. Such a system is being discussed in scientific literature, and its realization is possible.

In the second version, the difference in velocity is measured between two close and identical artificial earth satellites rotating in a single circular orbit at a low altitude over the Earth. The measurement of this difference in velocity makes it possible to find out the values of the geopotential at suborbital points, that is, at points of the projection of the artificial earth satellites on the Earth. It is difficult, of course, to implement this version: artificial earth satellites are not entirely identical, and they revolve not in a single orbit but in two close orbits. There is, however, no drawback to the designs. Also under discussion are Doppler methods for measuring the radial velocity in the pair and the use of a laser to irradiate both artificial earth satellites in order to photograph them against the background of the stars (we will recall the "photolaser").

Theoretically, this "satellite-to-satellite" measurement system in this version should make it possible to construct profiles of gravitational anomalies in the band along the artificial earth satellites' flight route. It is obvious, however, that the difficulties which prevent us from realizing this version are still insurmountable at this present stage of development of satellite geodesy.

The placing of corner light reflectors on the surface of the Moon by Soviet and American spacecraft gave rise to observations of the Moon in the interests of geodesy on a new methodological and theoretical basis. Laser sessions to determine the distance to the Moon have been conducted in the USSR, the United

States and France, and this work gave interesting results. The accuracy of a single measurement of the distance to the Moon using a laser built at the Physics Institute of the USSR Academy of Sciences imeni P. N. Lebedev amounts to ± 20 cm, which means a relative accuracy of $5 \cdot 10^{-10}$. The data from laser ranging of the Moon organized according to a suitable program in the course of a single night make it possible to determine the distance of observation stations from the Earth's axis of rotation. The accuracy with which the radii of parallels can be determined is about 1 dm. Using the results of laser ranging of the Moon over the course of a single month, one can determine the distances of observation stations from the plane of the Earth's equator, while a number of measurements taken over a prolonged period of time will make it possible to determine the movement of the Earth's poles.

We will note that the geodesic utilization of the results of laser ranging of the Moon requires a knowledge of the exact principles of its orbital movement, its axial rotation and its physical libration*, as well as a knowledge of the Earth's rotational velocity. Some of these demands on accuracy can be reduced by special organization of the observations. It is significant, however, that suitable arrangement and organization of the operations involved in laser ranging of the Moon will make it possible to carry out certain other reciprocal tasks, that is, the study of the principles of the orbital motion and libration of the Moon as well as the investigation of irregularities in the Earth's rotation about its axis.

Particular attention has been devoted in recent years to radiotechnical methods, the application of which in space geodesy has led to three prominent events: the precise determination of the Earth's gravitational constant, the discovery of mass concentrations on the Moon and the development of the possibilities for geodesic utilization of radio interferometers with a superlong baseline.

The value of the Earth's gravitational constant μ is equal to the product of the absolute gravitational constant and the mass of the Earth. The absolute gravitational constant is the coefficient of proportionality in the mathematical expression of the law of universal gravitation. The following is the general method for finding the precise value of μ according to spacecraft-tracking data: high-precision radiotechnical systems continually track the spacecraft, determining its range and the value of the radial velocity. According to approximated initial conditions and the adopted value of μ_0 (it is determined exactly), a numerical determination is made of the motion of the spacecraft along its orbit. This orbit is not geocentric, as in the case of an artificial earth satellite, but heliocentric, since the spacecraft moves not around the Earth but in the direction of the far planets, that is, around the Sun.

At the same time, the initial conditions for the motion of the spacecraft and the value of μ_0 are determined more exactly, and the calculated and observed ranges and radial velocities of the spacecraft are adjusted using the method of least squares. Essentially, an analogy of of this problem is the determi-

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*The Moon always turns one side to us, but it does "wobble" about this position (the "wobble" is not great--$\pm 5°$). This phenomenon is the physical libration of the Moon.

nation of gravitational acceleration using the method of free fall in a gravitational field; only in this case, there is no need to solve numerically the equation of motion: it is known that free fall takes place along a parabola, the form and dimensions of which are determined by the initial conditions.

Work has been carried out in the USSR and the United States on determining the value of μ exactly. The results from tracking the Venera, Mariner, Viking and Voyager spacecraft which were launched towards Venus, Mars and the other planets are strikingly coincident. This clearly illustrates the relative error of the average value from 11 independent determinations--less than 10^{-6}. In addition to the precise determination of μ, the specialists succeeded in using the data from radiotechnical tracking of long-range spacecraft to define precisely the mass of the Earth as well as the mass, dimensions and compaction of Venus and Mars.

High-precision radiotechnical tracking of the artificial lunar satellites of the Luna and Lunar Orbiter series have made it possible to detect regular "bursts" in the values of an artificial lunar satellite's radial acceleration. The radial accelerations, as in the case of the measurements in the high-orbit artificial earth satellite-low-orbit artificial earth satellite system, are obtained from the curves of the radial velocities. A painstaking analysis of the measurements has shown that these bursts are not the result of random instrument errors, since they were observed every time an artificial lunar satellite passed over the same segments of the Moon. This means that large anomalies in the Moon's gravitational field were characteristic of these segments.

Since the Moon lacks an atmosphere and there is no drag on its artificial satellites, they are launched into orbits very close to the surface of the Moon--at altitudes of 50-100 km. For this reason, scientists have managed to identify reliably the anomalous areas of the Moon's gravitational field on its visible side by using photographs of features on the lunar surface. It was discovered that the intensification of the Moon's gravitational field takes place solely over the lunar seas, for example, over the Sea of Brightness, over the Sea of Rains and certain others.

It is surprising that these large anomalies or, as they are called, mascons (from the abbreviation of the words "mass concentration") are associated with the lunar seas. There are many anomalous regions on the Earth as well, but they are basically encountered in mountains and in deep-water depressions of the world's oceans. Work done in the graviometric study of the far side of the Moon, carried out with the help of an artificial lunar satellite launched from onboard the Apollo-15 spacecraft, made it possible to create a map of the gravitational anomalies on the far side of the Moon. From this map it can be seen that there are no mascons on the far side of the Moon, and that all positive anomalies are associated with mountain regions.

The definitive guess as to the nature of mascons will be associated, in our opinion, with the future delivery to the Moon of an Earth-controlled craft with a graviometer installed onboard, that is, with the application (at a new stage) of traditional graviometric methods of studying the force of gravity.

In 1965, Soviet radio astronomers expressed an idea for a method of long-base radio interferometry, that is, radio interferometry with a superlong baseline (RSDB). The method of standard (short-baseline) radio interferometry spread extensively during the observations of artificial earth satellites. It made it possible to determine the direction to an artificial earth satellite using the simultaneous observations of a radio signal coming from the artificial earth satellite. The signal was observed using two antennas separated at a very precise known distance on the order of 1 km. A comparison of the phases of the signals received by the antennas makes it possible to determine the difference in the times of passage of the wave front at both antennas.

The product of the velocity of light and this difference in times gives the value of the segment characterizing the difference between the paths covered by the signal from the artificial earth satellite to the antennas, while the ratio of this length to the length of the baseline is equal to the cosine of the angle determining the direction to the artificial earth satellite (fig. 7). The small size of the baseline is necessary in this method as a condition for the essential parallel nature of the directions from the artificial earth satellite to the antennas. The development of standard interferometer technology has made it possible to increase the baseline to 5 km and use interferometers to search for naturally occuring radio sources as well, since the accuracy of these radio interferometers has exceeded 0.1" (we will recall that modern photographic methods provide direction with an error of no less than one angular second).

The greatest achievements in the development of the radio interferometry method as a means of high-precision astronomical and geodesic measurement, however, have been achieved on the very path to the creation of the RSDB method. It is based on the same principle as ordinary interferometry, but in RSDB, an important role is played by the fact that the difference in time between the recording of the signals by the antennas is obtained by comparing the tape recordings of simultaneous observations of the same naturally occuring radio signal by two radiotelescopes separated from one another by a great distance--on the order of several thousand kilometers. The presence of an independent time standard on each radiotelescope likewise plays a significant role.

In general, the RSDB method only became possible when extragalactic radio sources (quasars) with angular diameters on the order of 0.001" were discovered with the help of powerful antennas whose diameters exceeded 25-30 m. The availability of frequency generators with a high degree of stability, the creation of magnetic tape machines for recording large flows of information as well as the availability of computers on which the information received could be processed--all of these are factors in scientific and technical progress which make the application of the RSDB method a reality for the solution of reciprocal problems. Using the known directions to the quasars, one can determine: 1) the length of the baseline, that is, the chord on the Earth, with a relative error of less than 10^{-6}; 2) the angles characterizing the direction of the baseline with an accuracy of hundredths of an angular second; 3) the rotational velocity of the Earth or the length of a day and its variation with an accuracy on the order of thousandths of a second of time.

We are compelled to mention, however, that despite the fact that an accuracy comparable to the accuracy of laser ranging of the Moon (approximately $3 \cdot 10^{-9}$)
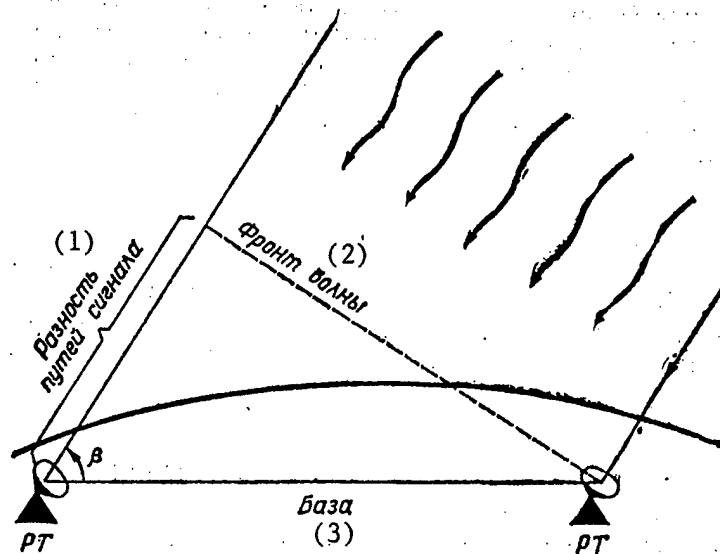
Fig. 7. Diagram of radio interferometric measurements
(β is the angle characterizing the direction to the source
of radiation)

Key:
1. Difference in signal paths
2. Wave front
3. Baseline

can be achieved using the RSDB method, the actual implementation of a geodesic
program on the basis of this method is limited at the present time by a number
of difficulties, one of which is the calculation of corrections for the pas-
sage of radio waves through the troposphere. These difficulties will be over-
come, of course, and the RSDB method will become one of the leading methods
in space geodesy. As was pointed out by Soviet scientist I. D. Zhongolovich,
a radiotelescope system encompassing the globe can prove to be the best method
of implementing and supporting a coordinate system for conducting global
geodynamic research.

Prospects for the Development of Space Methods of Geodesy

In conclusion, we will present certain considerations associated with the fu-
ture development of space geodesy. The fact of the matter is that, at the
present time, researchers can visualize with sufficiently clarity how to ap-
ply the existing space means and methods in order to solve the basic problems
of geodesy and geodynamics. As in the past, the basic task of geodesy remains
the determination of the measurements, shape and gravitational field of the
Earth. Work must be continued on further defining and developing large region-
al and global triangulation networks. Playing an important role in this is the
establishment of a single worldwide system of coordinates for highly precise
measurements, while at the second stage, it will be important to determine the
mutual positions of the points of origin and the orientation of the axes of
various systems of geodesic coordinates.

The opinion existing up until now that the Earth's center of mass must be the initial point of a worldwide system of coordinates may change. The problem of determining the center of mass within the body of the Earth has proven to be much more difficult than it was earlier assumed to be. In the exact statement of the problem, one must speak of the center of mass of the Earth-Moon system. The creation of new equipment will make it possible to study with a great degree of precision such subtle geodynamic effects relating specifically to the Earth-Moon system as the motion of the Earth's poles, the variation in the Earth's rotational velocity and the Earth's tides. The investigation of continental plate shift will continue, and one of the plans for a global service to track the movement of the continents will undoubtedly be implemented. The most precise investigations into the variations in the force of gravity will continue at the limits of accuracy (several microgals).

The development of space methods in the near future, however, will not be limited by the confines of the Earth. Although the prefix "geo" remains in the names of the scientific disciplines about which we speak, these methods have long ago become general for the study of the Solar System as a whole. A study of the gravitational field and shape of the Moon has been underway for a long time now. There are even attempts to introduce the term "selenodesy" into scientific practice (Selena is the ancient Greek name for the Moon). There is an idea to speak of determining the gravitational fields of the planets.

If one is to make more serious guesses as to the future of space methods, then one could imagine this sort of task: would it not be possible to create a unified approach to a system of coordinates within the framework of the Solar System which would help to connect these coordinates into a unified hierarchical structure?

The fact of the matter is that as a spacecraft flies to the far planets, it would cross over from the geocentric to the heliocentric system and then, for example, into an areacentric system. This latter system should be connected to the coordinate systems of the satellites of Mars, etc. If one were to imagine the difference in dimensions (scales) of these systems of coordinates, then it would become unclear how to satisfy common requirements for the relative accuracy of the coordinates determined. For the spacecraft itself, this problem is basically "reduced" by the possibility of adjusting its motion, and this is of considerable importance for the planets and their natural satellites. Since the exploration of the Solar System has begun and is continuing, the problem of establishing a unified system of coordinates for the Solar System will undoubtedly be solved.

TECHNOLOGICAL EXPERIMENTS ON HIGH-ALTITUDE ROCKETS

Moscow ZEMLYA I VSELENNAYA in Russian No 5, Sep-Oct 84 pp 27-34

[Article by M. S. Agafonov, candidate of technical sciences, V. L. Levtov, doctor of physical and mathematical sciences, and V. V. Savichev, doctor of technical sciences]

[Text] The production of new, improved and unique materials in space is a technological task of tomorrow. Experiments on high-altitude rockets are for establishing the scientific principles of such production.

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Why Specifically a Rocket?

The conditions for carrying out experiments with high-altitude rockets and on stationary orbital space vehicles (ZEMLYA I VSELENNAYA, No 3, p 25, 1979; No 2, p 28, 1982 -- Editor's Note) differ appreciably with respect to the level of microaccelerations characterizing the state of on-board weightlessness. Gaining a velocity several times less than is required for orbital flight, the rocket beyond the dense layers of the atmosphere moves as a body during free falling. At altitudes greater than 250 km, where the atmosphere is extremely rarefied, the rocket velocity is already insignificant. Accordingly, the braking caused by atmospheric drag becomes increasingly less. There are neither the vibrations nor the variable microaccelerations which aboard a station are caused by the work of the crew and operation of a great many complex systems. Direct measurements made using special high-response accelerometers have revealed that the level of microaccelerations in the passive segment of rocket flight is not greater than $10^{-6}g_0$ (g_0 is the acceleration of gravity at the earth's surface), whereas on a station it is 10^{-3}-$10^{-4}g_0$.

Another significant feature of research aboard a rocket is a relatively brief duration of the state of weightlessness (up to 10 min). The implementation of experiments under such conditions requires the use of so many accelerated regimes of melting and crystallization that initially many specialists in the field of study of materials doubted the feasibility of such experiments. For example, the supposition that in 10 minutes it is possible to obtain perfect monocrystals of an acceptable size completely contradicts the initial ideas. And nevertheless there are many materials of practical interest whose technological processing is feasible during this time without sacrifice of quality.

The fact is that due to the short duration of the experiments it was not possible to reach a stationary regime of the process of convective heat and mass transfer and specifically to a great extent they determine the mechanisms of growth and final structure of the ingots. The absence of convection during brief weightlessness is one of the principal factors resulting in an improvement in materials.

In addition, experiments on rockets also have other merits. Great load-carrying capacity, short time required for preparation and high frequency of launchings afford a possibility for carrying out a considerable number of experiments and for obtaining results on a routine basis. Less rigorous requirements on equipment with respect to ensuring crew safety to a great extent simplify the development of the apparatus and accordingly lessen expenditures on the experiment.

Rocket as an "Express Laboratory"

In our country experiments with high-altitude rockets began when specialists had just begun to proceed to systematic research on space technology problems. The small volume of information obtained experimentally by that time and the considerable lack of clarity in the theoretical premises were reflected to a considerable degree in the initial strategy for research. The investigations were made simultaneously in virtually all the principal directions in the technology of production of inorganic materials. The experiments were executed time and again in order to increase the reliability of the results.

The processing of materials at high (above 1000°C) temperatures under conditions of rigorous restrictions on the time of the experiment requires heating elements with a high power and a forced cooling system. After all, a sample must not only be melted, but also must be hardened under weightlessness conditions.

Taking into account the limited availability of power on the rockets, the electric furnaces such as used on manned stations were ill-suited. Special "exo-furnaces" were employed for rapid heating of the samples. The strength of construction made it possible to install them aboard rockets without a parachute so that with landing accelerations greater than 3000 g_0 the samples remained intact. The size of the ingots selected for the rocket experiments was approximately the same as for experiments on orbital stations so that the subsequent results would be simpler to compare.

In one of the series of experiments on a rocket oriented relative to the sun a study was made of the possibility of using radiation concentrators for the containerless fusion of materials.

The influence of weightlessness on the technological process begins to take hold after transition of the material into a fluid or gaseous state. The principles for developing a technology for improving the structure of samples are based specifically on the change in regularities of behavior of matter in these aggregate states.
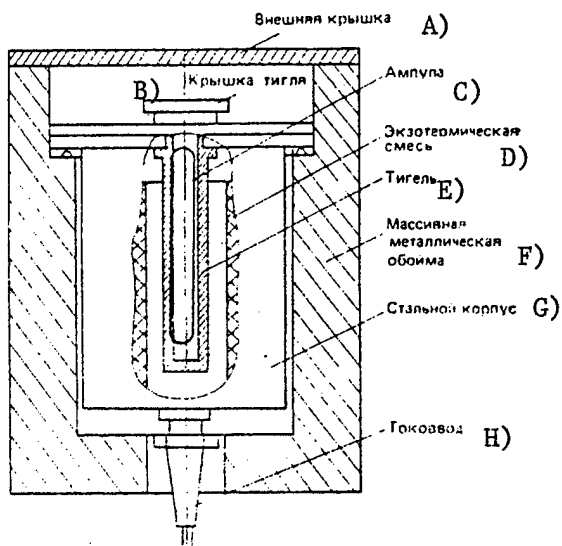
Fig. 1. Diagram of exothermic furnace.

KEY:
   A. Outer cover
   B. Crucible cover
   C. Ampule
   D. Exothermic mixture
   E. Crucible
   F. Massive metallic ring
   G. Steel body
   H. Current input

Fig. 2. Apparatus with concentrators (paraboloids) in whose focal spot the containerless fusion of materials on a pedestal was studied under space conditions.

KEY:
   A. Accelerometer
   B. Solar radiation concentrators
   C. Screen with drive

The first principle is related to use of the effects of a decrease in the intrinsic weight of the body, the Archimedes repulsion force and hydrostatic pressure under weightlessness conditions. Without significant energy expenditures this makes it possible to realize containerless holding of samples and therefore obtain stable systems of components with different density. The latter affords prospects for developing composition materials (they contain strengtheners in the form of filaments, fibers, particles, etc.), as well as alloys of homogeneous composition with a region of immiscibility (components of such an alloy do not dissolve in one another even at a temperature above the melting point and under ordinary conditions are rapidly stratified due to a substantial difference in specific gravities).

The second principle is based on the change in mechanisms of heat and mass exchange in melts, solutions and mixtures due to a lessening of the role of gravitational, thermal and concentration convection. This is of interest for the growing of three-dimensional monocrystals with a uniform distribution of alloying admixtures.

Under weightlessness conditions the behavior of a fluid is determined by molecular surface tension forces which, as is well known, strive to impart to the surface a form corresponding to the minimum energy (by definition surface tension is the energy which must be expended for increasing the fluid – saturated vapor interface per unit area). In this connection wettability at the fluid-

solid interface begins to play an important role, as well as effects at other phase surfaces (between substances having different physical and chemical properties: fluid-other fluid, melt-crystal, etc.). The third principle of space technology is based on use of surface phenomena.
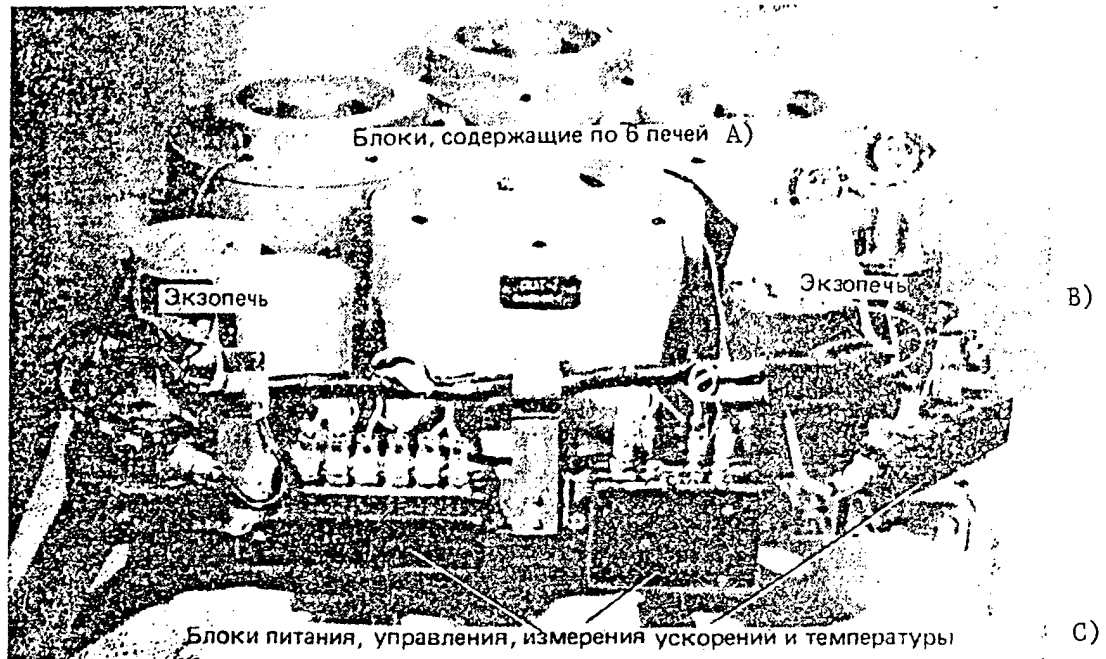
Fig. 3. General appearance of "Sprint" apparatus, in course of one rocket launching making it possible to carry out 32 melts of materials simultaneously.

KEY:
A. Blocks each containing 6 furnaces
B. Exothermic furnace
C. Electric power block, control block, block for measuring accelerations and temperature

Experimental Results

Several directions in production are now being considered for which space technology can yield significant advantages. In addition to the production of materials themselves (for the time being in small volume: special alloys with unique properties, composition materials, semiconductor monocrystals, etc.), space research is assisting in a more detailed study of crystallization processes and is facilitating the development of earth-bound technology. What has experimentation aboard high-altitude rockets yielded for solution of these problems?

Metals and alloys. Experiments in which the melting and crystallization of ingots of iron, titanium, nickel and other metals have been carried out in a

wettable crucible have shown: with good adhesion to the crucible walls the structure of the samples obtained in space differs little from the structure of its prototypes prepared on the earth using the same apparatus. It was established in the examples of magnetic superconductors and some other special melts that within the ingots processed in space the structure is coarser-grained and sometimes zones of new phases appear having a chemical composition not characteristic of terrestrial prototypes. This may be related to a shifting of thermodynamic equilibrium accompanying phase transitions during weightlessness, a change in the mechanisms of forming and crystallization of individual phases. But most frequently crystallization began from the walls of the crucible, and unnecessary admixtures entered the sample from the walls. Gas, always present in a solid, during melting was released uniformly in the volume and formed pores of a spherical configuration measuring from 10 to 300 μm which had a tendency to move toward the center of the ingot and were joined into a large cavity.

The crystallization process occurs completely differently if the container is made from a material not wettable by the melt and its volume is larger than the volume of the billet. In this case a spherical drop is formed after melting which can float freely within the container. With accelerations on the order of 10^{-6} g_0 the force tending to press the melt against the wall is many times less than the force of surface tension. For this reason the influence of the walls on crystallization of the sample can be neglected. In fact, the sample is in contact with the wall at only one point and in a random way, since the direction of the acceleration vector changes with time. A merit of such a crystallization regime is that it is simpler and does not introduce additional disturbances during hardening because there is no special acoustic or electromagnetic holding system.
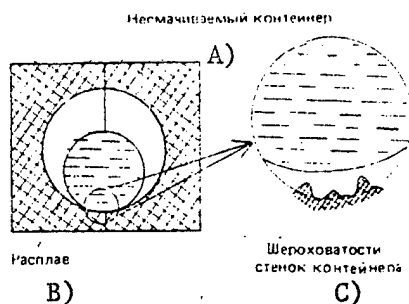
Fig. 4. Diagram of "containerless" melting of drop samples.

KEY:
    A. Unwettable container
    B. Melt
    C. Roughnesses of container wall
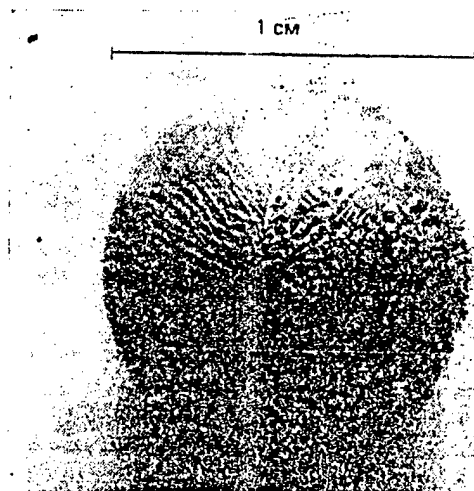
Fig. 5. Spherical sample of copper measuring 9 mm obtained from melt drop. The network on the surface was formed by the dendrite. The dendrite itself was formed with a monocrystalline type of texture.

Samples of pure silver and copper, obtained using the similar "quasi-container-less" method, had a configuration which deviated from spherical by not more than 1% (diameter of samples 5-10 mm). The structure of their surface indicated that crystallization transpired without contacts with the container walls. An analysis revealed that the structure of the copper samples is characterized by clearly expressed dendrites -- a dendritic, branching form (from one to three in a sample). The shafts of the dendrite branches grew virtually without distortions until they emerged at the surface and there formed a regular cellular structure. The undistorted structure of the dendrite indicates absence of mixing of the melt during hardening and a considerable supercooling below the crystallization point. The supercooling phenomenon is characteristic of containerless methods because when obtaining pure materials there is no generation of growth of crystals from the walls. With sufficiently great cooling rates such as realized in apparatus with solar energy concentrators, when the light flux is cut off, using this method it is possible to obtain volumetric samples of metals and other materials with amorphous, glassy structure and unique physical properties.
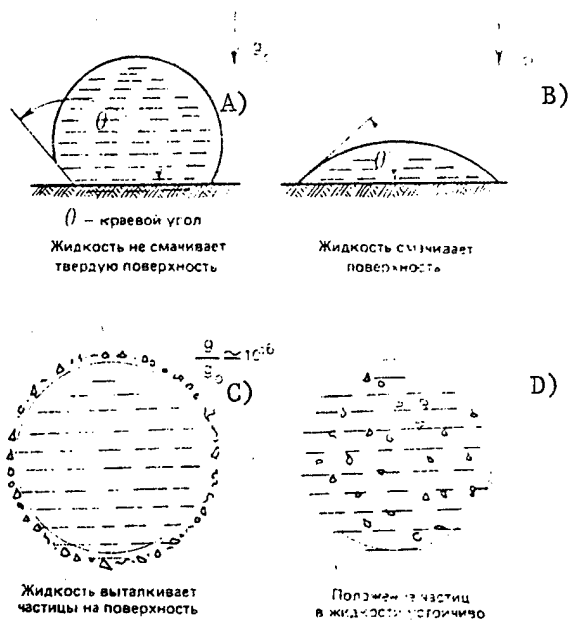
Fig. 6. Wettability of surface (at top) and resistance of composition materials to separation under weightlessness conditions (at bottom).

KEY:

A. $()$ -- contact angle. Fluid does not wet solid surface
B. Fluid wets surface
C. Fluid expels particles to surface
D. Position of particles in fluid is stable

Composition materials. The process of phase separation transpires quite intensively in a melt on the earth due to the difference in specific gravities of the main component and filler. Accordingly, it is difficult to obtain a composite which is homogeneous in volume even from a billet with a uniform initial distribution of particles prepared by the powder metallurgy method. Under weightlessness conditions the separation process is slowed by tens of thousands of times and a substantial positive effect can be expected, particularly in accelerated regimes. In actuality, samples of a heat-resistant nickel-aluminum alloy strengthened by chromium carbide, as well as samples of an aluminum alloy reinforced by graphite fibers with a coating of silicon and molybdenum carbide, had a high degree of uniformity of distribution. However, samples with a copper-graphite composition were markedly inhomogeneous. It was found that the wettability of particles by the melt of the main material exerts a decisive effect on the resistance of composites to separation.
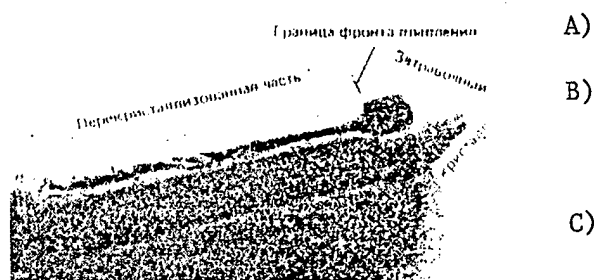
Fig. 7

Dislocation-free monocrystal with uniform distribution of admixture (diameter 8 mm) obtained by ordered crystallization at rate of 10 mm/min.

KEY:
    A. recrystallized part
    B. Main fusion front
    C. Seed crystal

Usually the wettability of a solid surface is characterized by the contact angle which a fluid droplet forms with the surface. If this angle is less than 90° the material is considered wettable; if the angle is greater than 90° it is considered unwettable. We note that the energy of interphase tension is great for unwettable composites. Now we will examine the opposite case when the small particles are placed in the fluid under weightlessness conditions. Here the unwettable system will have a minimum surface energy if all the particles have been expelled to the surface. In a wettable system, however, the position of the particles in the fluid volume is stable and also corresponds to an energy minimum, as was observed experimentally.

The contact angle is about 140° for a copper-graphite system. The graphite powder was expelled to the surface, whereas the core was an ingot of pure pore-free copper. In the next experiments a 3% admixture of chromium was introduced. The chromium carbide forming on the graphite surface at a temperature above

1100°C is wetted by the melt (angle 40-45°). An improvement in wetting at
the interface of the phases considerably increased the uniformity of graphite
distribution in samples.

Затравочный кристалл A)   Расплав B)   Ампула C)

D)   E) Граница фронта кристаллизации   F)   G)

Температура, C°   Максимальная
Точка кристаллизации H)
Минимальная I)

Шероховатость
стенок
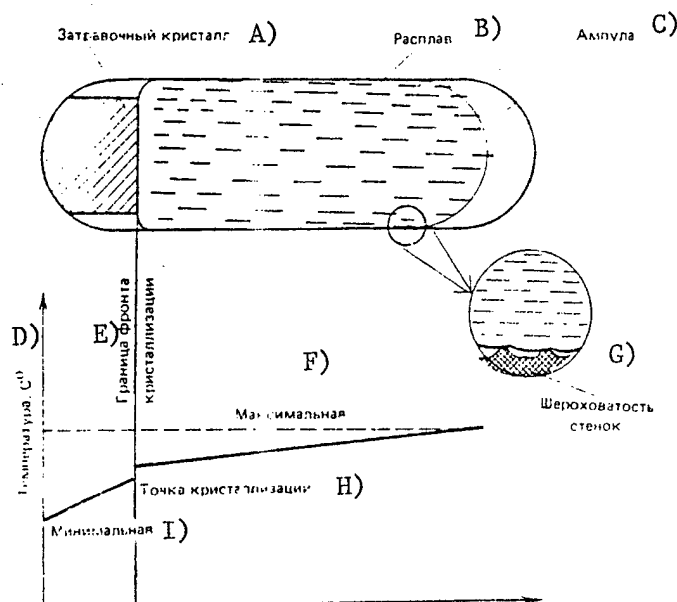
Fig. 8. Diagram of ordered crystallization in ampule.

KEY:

A. Seed crystal
B. Melt
C. Ampule
D. Temperature, °C
E. Crystallization front boundary
F. Maximum
G. Wall roughness
H. Crystallization point
I. Minimum

Alloys with immiscibilty region. Samples of aluminum-lead and copper-chromium
systems were selected for the experiments. These were prepared by the powder
metallurgy method. These materials are used in wear-resistant glide bearings
in precise instruments and erosion-resistant highly precise contacts. The re-
melting of ingots under weightlessness conditions resulted in stratification
of the components even in accelerated regimes during a time of about 150-200
sec. As in the case of a copper-graphite composite, the separation mechanism
is governed by surface tension forces at the boundaries between phases.

Semiconductor materials. Most of the experiments were carried out with samples
of germanium and silicon because they are used most extensively in industry

and the method for determining their properties has been well developed. Monocrystalline samples in evacuated quartz ampules were placed in a crucible on whose walls a near-linear temperature drop was formed. Only a part of the sample was melted; the remaining part served as a charge. Ordered crystallization of the melt occurred with a temperature decrease in the crucible. A study of the surface of the ingots returned from space revealed that in the course of growth they came into contact with the ampule walls only in individual zones. Control samples prepared using similar apparatus on the earth had full contact with the walls and their structure was semicrystalline.

During experiments on rockets it was possible to obtain monocrystalline ingots with a low density of dislocations (linear defects of the crystal lattice) with a rate of growth 7-10 mm/min. This exceeds the rate of growing of germanium and silicon monocrystals on the earth by more than an order of magnitude. Such samples were obtained for the first time in world practice. X-ray structural analysis and metallographic research have demonstrated that they have a high degree of structural perfection and have a uniform distribution of the alloying admixture.

An improvement in the structure of monocrystals was favored by several factors, especially a change in the nature of the interaction between the melt and the ampule walls and an absence of convective mixing, which cannot develop in the volume. On the earth the melt is pressed toward the walls by its own weight. This is adequate for the thermoelastic stresses on the crystallization front, pressed by the walls, to exceed the plastic limit and cause the appearance of a great number of dislocations in the crystal, up to the formation of fractures. Under weightlessness conditions the melt is acted upon only by capillary pressure caused by surface tension on the free spherical meniscus. The pressure at any point should be identical and the melt surface everywhere has an equal curvature. This results in formation of the effect of "hovering" of the fluid on small irregularities of the ampule walls. In actuality, less than 1% of the melt surface is in contact with the wall. Its remaining part, including the meniscus directly at the crystallization front, remains free.

Thermocapillary convection was observed experimentally using the "Pion" onboard shadow instrument (ZEMLYA I VSELENNAYA, No 1, p 2, 1982 -- Editor's Note). Near the free surface movement in actuality arises more rapidly -- in 0.1 sec, but mixing of the entire fluid volume requires tens of minutes. Accordingly, in experiments on rockets this more powerful convection mechanism, unrelated to accelerations, also could not exert an influence on the crystallization process.

As indicated by theoretical evaluations, in the case of small convective mixing the transfer of heat and mass is determined by diffusion and it is possible to obtain maximum rates of crystallization of germanium and silicon -- up to 18 mm/min for samples with a diameter of 6-8 mm. Due to the high rate of cooling in the experiments it was possible to achieve corresponding regimes. The rate of movement of the crystallization front was greater than the rate of "growth" of the dislocation from the seed crystal. Without giving a detailed analysis, we point out that precisely an accelerated crystallization regime ensured a uniform distribution of admixtures through the volume of the

monocrystals. The crystallization front was maintained flat to the end of the process. A uniform distribution of admixtures is a highly important indicator of perfection of semiconductors, determining their electrophysical properties. In experiments with complexly alloyed silicon a study was made of the behavior of admixtures during accelerated crystallization. It was found that a surface-active substance, which lessens surface tension, was concentrated for the most part in the outer part of the ingot. An inactive admixture (boron) had a uniform distribution.

Конечная точка кристаллизации   A)

Зона контакта с ампулой   B)

Направление вытягивания

A)

Кристалл   B)

Рабочий мениск   C)

Расплав   D)

Смачиваемый формообразователь   E)

Несмачиваемая вставка   F)

Мениск, задающий давление   G)
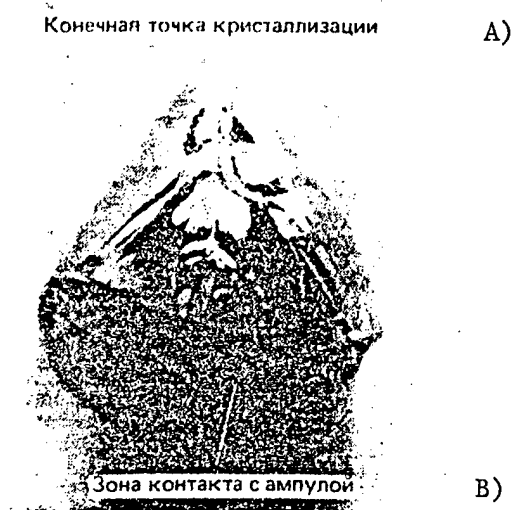
Fig. 9. Germanium monocrystal after droplet crystallization.

KEY:
  A. Final crystallization point
  B. Zone of contact with ampule
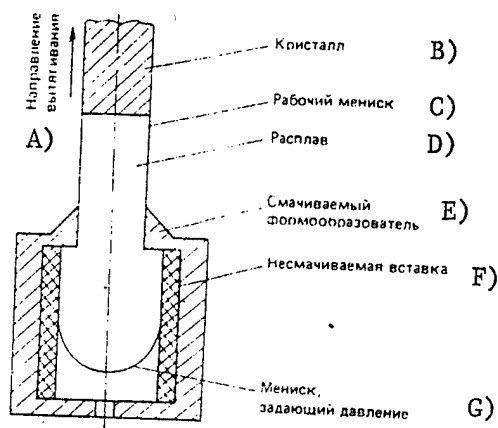
Fig. 10. Diagram of growth of shaped crystals obtained by A. V. Stepanov method (capillary shaping).

KEY:
  A. Direction of extraction
  B. Crystal
  C. Working meniscus
  D. Melt
  E. Wettable shaper
  F. Unwettable insert
  G. Meniscus imparting pressure

It was possible to obtain interesting results in the course of study of crystallization of free droplets of semiconductor materials. For example, experiments were carried out with samples of germanium. In the zone of contact with the ampule pores were formed as a result of H_2O evaporation from small quartz flasks at a temperature above 1200°C. In contrast to experiments with the hardening of spherical droplets of metals, for which there can be heat transfer through both the fluid and solid phases and the angle of growth (this characterizes the correspondence between the form of the melt and the form of the crystal) is equal to zero, all the germanium ingots had the form of an onion bulb. Theoretically the form is attributable to the non-zero angle of growth, as was observed in actual practice. An analysis of the structure of the samples

indicated that in some cases they were crystallized from the center of the droplet.

Capillary shaping. One of the promising directions in space technology is the obtaining of articles of a stipulated configuration, such as optical elements (lenses, spheres, etc.), thin-walled hollow components and parts of a definite shape due to surface tension forces. Optical elements with a high quality of surface, not requiring additional processing, can be fabricated from vitreous media which are not subject to shrinkage or expansion during hardening. However, experiments with different kinds of glass on rockets for the time being have not given a positive result because it is extremely difficult to melt a transparent sample and cool it in a short time in exothermic furnaces.

An experiment was carried out on a high-altitude rocket for the first time for growing crystals with a particular shape. A convenient method for obtaining such crystals was developed by the Soviet scientist A. V. Stepanov. The essence of the method is that the crystal grows from the meniscus of a melt whose shape is generated by a special shaper. The good prospects for such a method are evident: it is possible to organize an automatic continuous process for obtaining crystals immediately having the shape required for use in instruments. This can be done using simple equipment because, according to theory, the stability of the meniscus is increased by many times under weightlessness conditions. Copper was the first experimental metal. When the samples were returned from space their shape was exactly as intended. The experiment was repeated later with silicon. The experiments indicated that the shape of the samples grown by the Stepanov method is easily controlled by changing the pressure of the melt. This can be done using the same capillary forces, varying the curvature of the meniscus within the crucible and changing the dimensions of the unwettable surface.

Scientific Significance of Experiments

It has now become clear that technological experiments on rockets, affording accelerated regimes for the processing of materials for space technology, constitute an important class of experiments of independent importance. They confirmed the possibility of improving the quality of different materials, made it possible to study the characteristics of containerless crystallization and methods for capillary shaping and to check the principles for constructing promising technological apparatus and instruments (such as accelerometers, direct solar heating furnaces, apparatus for containerless preparation of samples, etc.). Some of the results are of the greatest importance for Soviet science. High efficiency and encouraging results make it desirable to develop experimental work further on the problem of accelerated crystallization of ingots.

5303
CSO: 1866/18

'SVIT' COMPLEX FOR ANALYSIS OF SPACE PHOTOGRAPHY

Moscow MOSKOVSKIY KOMSOMOLETS in Russian 15 Jan 85 p 4

[Article by Ye. Nelepo]

[Extract] Mysterious things were happening on the screen of a television monitor: a plain black-and-white image with blurred outlines was gradually becoming sharper and acquiring color. A strenth of the Moscow River that appeared as a blue band could now be clearly seen, and a winding brown stripe running next to it came into focus. The stripe was hot water discharged from a Moscow factory. A yellowish green spot appeared spot appeared in the place where the two joined. Each temperature had its own color.

All of these transformations took place in a matter of minutes. They were produced by a new computerized image-processing complex which has been developed at the USSR Academy of Sciences' Institute of Space Research. This complex is called the "SVIT", which is an acronym of 'self-contained video information terminal'. Candidate of Physical-Mathematical Sciences L. Chesalin, one of the developers of the complex, related:

"State-of-the-art space technology makes it possible to obtain a tremendous number of pictures of our planet's surface. Photographs from space represent a qualitatively new type of information.

"The time has passed when specialists drew certain conclusions simply by glancing at such pictures. Aerospace video information must now be processed in detail and systematized. Only a specialized equipment complex is capable of coping with this task. What requirements are made of such a complex?

"It must store several pictures at the same time, display them on the screen of a television monitor in a form to which people are accustomed, and perform certain operations for the transformation of the images: enlarging and reducing them, shifting individual parts of them, presenting black-and-white pictures in legend colors, and so forth. The aerospace video-information processing system must be interactive, that is, it must permit the operator to intervene in the course of the solution of a problem and to determine the sequence and type of operations.

"The 'SVIT' meets all of these requirements. Moreover, our complex is advantageously distinguished from similar systems by the fact that it contains components that are serially produced in the USSR and are therefore relatively inexpensive: an 'Elektronika-60' microcomputer, 'VZOR' television cameras, an 'IZOT 5003' tape unit, and a number of others.

"In addition to a conventional computer memory, the new complex has a special video-information storage device which permits the storing of as many as 10 pictures at once. The fact that pictures take up a very large space in a computer's memory makes such a device necessary.

"One very important fact is that the creators of the 'SVIT' developed software for it which allows it to be controlled by practically any person who is not trained in programming.

"The fact that practically any black-and-white picture can be presented in lengend colors with the aid of the complex is another of its important features. The human eye distinguishes shades of color far better than degrees of black-ness. A specialist sees a mass of fine details in a color picture which he did not notice previously. One can be readily convinced of this by comparing an initial black-and-white photograph of that same stretch of the Moscow River, for example, with a picture of the stretch which has been made in artificial colors from this photograph. Waters with different temperatures have different shades in this picture.

"Incidentally, these and many other pictures were made and processed with the aid of the 'SVIT' in line with a program for heat-radiation studies of municipal service facilities of Moscow during the year 1983."

FTD/SNAP
CSO: 1866/79

UDC 061.3:502.3:629.78

TENTH CONFERENCE OF WORKING GROUP OF SOCIALIST COUNTRIES ON REMOTE SENSING
OF EARTH UNDER 'INTERCOSMOS' PROGRAM (ULAN-BATOR, 26 JUNE-2 JULY 1984)

YEGOROV, V. V.

[Abstract] The conference was attended by specialists from Bulgaria, Hungary,
GDR, Cuba, Mongolia, Poland, Romania and Czechoslovakia. It summarized the
results of work of the Working Group of Socialist Countries on Remote Sensing
of the Earth (WGRS) for the past year and discussed the research planned for
1986-1990. The first stage of the "Black Sea" experiment was carried out in
August-September 1983 with the participation of East German, Mongolian, Polish,
Romanian and Soviet scientists. Data on hydrophysical, biological and optical
parameters of the sea surface were collected from the "Soyuz-7" and "Meteor-
Priroda" satellites, and AN-30 flying laboratory, the research ships "Professor
Kolesnikov" and "Kometa" and from an oceanographic platform at Katsiveli. In
June 1983, in the Sheki-zakatal'skiy test range in Azerbaijan, in preparation
for the "Gyunesh-84" experiment, Soviet specialists made spectral and multi-
level photographic and biogeophysical measurements of soil-vegetation complexes.
Experiments were carried out in test areas in Mongolia ("Spektr-Mon-83") and
Cuba ("Sugar Cane-84") with Mongolian and Cuban specialists assisted by Russian
and Bulgarian scientists. Surface spectrometric measurements of natural pasture
vegetation in Mongolia were supplemented by a photographic survey from the
"Salyut-7." Soviet and East German specialists reported on preparations for
publication of an atlas of interpretation of multizonal aerospace photographs.
A report on the "Gobi-Khangay-81" experiment was presented. Preparations for
a multilingual terminological-interpretive dictionary of remote sensing terms
are being completed; it will include equivalents in German, Czech and Polish.
The conference approved a catalogue of joint research projects for 1986-1990.
The program emphasizes four main themes: study of geosystems by remote methods;
study of world ocean and closed water bodies with allowance for influence of
atmosphere; study of geological structures by remote methods; improvement of
methods and instrumentation for remote measurements and processing of results.
During the conference there was also a seminar on methods for remote sensing in
geological research. Twenty-seven reports were presented on such subjects as
the "Gobi-Khangay-81" experiment, evaluation of hydrological conditions in arid
parts of Mongolia, digital processing of a lineament network in a phosphate
deposit, use of aerial photographs in study of Antarctic geology, geological
structures in Cuba, linear and annular structures in western Czechoslovakia,
spectrometric measurements of rocks and ores and compilation of space geology
maps.
[54-5303]

YEAR-TO-YEAR VARIABILITY OF COMPONENTS OF EARTH'S RADIATION BUDGET ACCORDING TO SATELLITE MEASUREMENT DATA

MARCHUK, G. I., academician, KONDRAT'YEV, K. Ya., corresponding member, USSR Academy of Sciences, AVASTE, O. A., KOZODEROV, V. V. and KYARNER, O. Yu.

[Abstract] For the purposes of the "Razrezy" program it is necessary to have the year-to-year variability of the radiation budget components, not their mean values. The authors give an analysis of such year-to-year variability computed on the basis of systematized satellite measurements with scanning radiometers carried by polar orbit satellites. Solar-synchronous orbits made it possible to carry out measurements over the same territory twice each day (0900, 2100 LT). The data were reduced to mean monthly values of the fluxes of outgoing short- and long-wave radiation. The analysis of year-to-year variability was based on mean monthly values of the radiation budget, its short- and long-wave components and incident solar radiation within the limits of a grid with a 2.5° x 2.5° interval for the entire earth. The results of computations of the standard deviations of the radiation budget and its components relative to their mean monthly values are represented in three full-page isoline maps (Figures 1-3). Figure 1 shows the following regions of significant year-to-year variability: Sahara Desert, Kuroshio Current, Gulf Stream region, Peruvian upwelling, near Cape Horn, in Gulf of Guinea, east of Newfoundland, tropical Atlantic near South America, deserts of Central Asia and South Africa, certain parts of Pacific Ocean, Norwegian Sea. These potential energy-active zones are not necessarily zones of substantial variability of heat exchange between the underlying surface and the atmosphere, but may be related to cloud cover anomalies, to high energy and mass exchange in the atmosphere, to dynamic atmospheric effects and other factors. Figure 2 shows the radiation budget albedo component, whose main variability is associated with cloud cover. The greatest variability is in the equatorial regions of the Pacific, Indian and Atlantic Oceans. Figure 3 shows the year-to-year variability of the long-wave component; the highest values are in the Sahara Desert, along the east coast of the Asiatic continent and in North America. The satellite data made it possible to differentiate regions of year-to-year variability with an amplitude of the radiation temperature of the system of 4-5 K. Existing satellite systems can therefore be used in evaluating climatic "signals" in the atmosphere because the errors in "instantaneous" measurements of such systems are 1.5-2 K. There are ways in which these errors can be reduced. Figures 3; references 4: 2 Russian, 2 Western.
[62-5303]

UDC 551.501:629.78

ONE APPROACH TO REMOTE SENSING OF TOTAL OZONE CONTENT

RYZHIKOV, G. A., BIRYULINA, M. S. and ROZANOV, V. V., Leningrad State
University imeni A. A. Zhdanov

[Abstract] Various methods have been proposed for determining the vertical
distribution of ozone and its total content, but they require the use of
a priori statistical information, which is not always adequate for many parts
of the earth, thus giving rise to systematic errors. Accordingly, the authors
propose a method for determining total ozone content by the interpretation of
satellite measurements without the use of a priori information. The basis of
the method is an equation for the "value of information" proposed by G. I.
Marchuk in an article "Equation for the Value of Information From Meteorological
Satellites and Formulation of Inverse Problems" in KOSMICH. ISSLED., Vol 2,
No 3, pp 462-477, 1964. This is used in formulating the inverse problem of
determining total ozone content. It involves the joint registry (by an
artificial earth satellite) of outgoing thermal radiation in the band 9.6 μm
of ozone and scattered ultraviolet radiation in the wavelength range 0.25-
0.31 μm. The necessary formulas are derived for this purpose, not involving
any use of a priori information. The method is compared with statistical
approaches. Series of evluations obtained by different methods are presented.
It is clearly demonstrated that the separate use of measurements only in UV
region or only in the IR spectral region do not give a satisfactory accuracy
in retrieving the total ozone content without use of a priori information.
Combined measurements and use of the equation for the value of information
give the best possible data. Tables 3; references 18: 11 Russian, 7 Western.
[54-5303]

UDC 551.51:551.507.362

SCHEME FOR ATMOSPHERIC THERMAL SENSING FROM SATELLITES WITH ENHANCED VERTICAL
RESOLUTION

USPENSKIY, A. B., SUTOVSKIY, V. M. and TRET'YAKOV, V. Ye., State Scientific
Research Institute for Study of Natural Resources, Moscow

[Abstract] According to theoretical estimates and the results of processing
of satellite information, for existing remote thermal sensing systems and
artificial earth satellites the mean square error in determining temperature
σ_T and vertical resolution in the troposphere (in the layer $p \gg 100$ gPa) is
2.5 K and 4-5 km, which does not meet the requirements of numerical forecasting

schemes (about 1.5 K and 2 km). The objective of this article is a brief analysis of the definitions and quantitative evaluations of vertical resolution in the inverse problem of remote thermal sensing using an approach developed by the authors for evaluating the possibility of improving the accuracy and resolution of the results of remote thermal sensing by use of a scheme in which measurements of outgoing IR radiation in several spectral intervals are combined with similar measurements at several angles to the nadir. A review of the literature indicates that two sources give the best approach to joint investigations of resolution: B. T. Conrath, J. ATMOS. SCI., Vol 29, No 7, pp 1252-1261, 1972, and A. B. Uspenskiy, et al., TRUDY GosNITsIPR, No 7, pp 92-101, 1979. In this article emphasis is on increasing vertical resolution by a combination of nadir and slant soundings. The different measurement schemes used for this purpose are discussed. Five different sensing methods are examined. It is shown that a combination of measurements at the nadir with measurements at an angle of 45° is an effective means for increasing vertical resolution in remote thermal sensing. Figures 1; tables 1; references 12: 4 Russian, 8 Western.
[54-5303]

STUDY AND MAPPING OF ANTHROPOGENIC EFFECT ON ENVIRONMENT IN DIFFERENT REGIONS OF USSR ON BASIS OF SPACE PHOTOGRAPHS

KONTOBOYTSEVA, I. S. and KRAVTSOVA, V. I.

[Abstract] The article gives the results of experiments for compilation of maps of the anthropogenic effects on the environment. The work was based on the most used types of space photographs: high-resolution scanner photographs and photo-images from manned spaceships and orbital stations. Photographs were analyzed from four regions (Northern Dvina Basin, Lower Volga Region, Ustyurt Plateau, Karakum Desert and oases). The maps show type of land use and the unfavorable effects of land use. Multizonal scanner photographs from the "Meteor" satellite were used in mapping the anthropogenic effect on forest vegetation of the headwaters of the Northern Dvina, with interpretation in three zones: orange (0.6-0.7 μm), red (0.7-0.8 μm) and near-IR (0.8-1.1 μm). The anthropogenic effect in grain cultivation regions was mapped using scanner phographs of the Lower Volga region from the "Landsat" satellite. Mapping of the anthropogenic effect on desert landscapes was carried out in the Ustyurt Plateau from a scanner phograph taken from the "Meteor" satellite. Another desert sector (with oases) in the Karakum Desert was mapped using a photograph taken from the "Salyut-4" orbital station. These four "anthropogenic effect" maps are reproduced as Figures 1-4 accompanying the article. Each of these examples is briefly discussed. The usefulness of such maps is described. Figures 4; references: 5 Russian.
[43-5303]

MULTIPLE REGRESSION ANALYSIS OF PHOTOGRAPHIC IMAGE OF SOIL PROPERTIES

VINOGRADOV, B. V., RIEDEL, C. and KAPTSOV, A. N., Evolutionary Morphology
and Ecology of Animals Institute imeni A. N. Severtsov, USSR Academy of
Sciences, Moscow; Martin Luther University, GDR

[Abstract] Surface and remote studies of the spectral properties of soils and
characteristics of the photographic image on multizonal photographs were
carried out in an aerospace test range in the GDR central plain. An aerial
survey was made with an MKF-6 camera; surface photographs of standard soil
samples were taken in the same spectral intervals. The experiments were
carried out under natural conditions with diffuse illumination. Only air-dried
soil samples were used. The optical density of the image of each soil and an
optical wedge were measured on the negatives. A target measuring 1 x 1 cm
with 10,000 measured values was selected on the image of each soil and the
mean optical density of the negative was then computed. All measurements were
scaled to the optical density of the positive image. The correlation between
the optical density of the positive photographic image D_{pos} and the soil
properties (humus content, iron oxides and carbonates) in the upper genetic
soil horizon was measured. The correlation is described by the linear function
$Y = a + bX$, where $Y = D_{pos}$, X is the soil factor, $a = D_{pos}$ of the soil with
X = 0, b is the index for the Y(X) gradient, this making it possible to derive
a number of special linear correlation equations (relationship between D_{pos}
and soil properties mentioned above). These and other formulas whose deriva-
tion is given in the article make it possible to determine the joint photo-
graphic effect of a combination of different properties of the air-dried
soils. The multiple regression equation and its derivatives are useful in
interpreting aerospace images of soils. Figure 1; references 6: 2 Russian,
4 Western.
[1866-33]

IDENTIFICATION OF STRUCTURE OF SOIL-VEGETATION COVER USING AERIAL AND SPACE
PHOTOGRAPHS

GOROZHANKINA, S. M. and KONSTANTINOV, V. D., Forestry and Timber Institute
imeni V. N. Sukachev, Siberian Department, USSR Academy of Sciences, Krasno-
yarsk

[Abstract] Experience with the discrimination of soil and vegetation structures
in the taiga part of Western Siberia from space and aerial photographs is
described. Emphasis is on the discrimination of structures at different

scales. It is clear that interpretation, initial systematization and mapping of soil-vegetation cover structure requires a set of images forming a series in the range 1:10,000,000 to 1:10,000. The following scales are discussed: 1:10,000,000; 1:2,500,000; 1:1,000,000; 1:200,000-1:150,000; 1:50,000; 1:15,000. The particular value (information content) of each of these scales is considered. This is indicated by a series of photographs (with keys) at different scales which accompany the text. In this series of photographs each scale successively reveals more clearly the contents shown on the smaller-scale photograph preceding it and serves as a key for it. The mega- and macrostructures appearing on space photographs correspond most closely to the purposes of general soils-geobotanical regionalization. The maps of meso- and microstructures compiled on the basis of photographs can serve as a conditional base for a detailed soils-geobotanical regionalization corresponding to the direct needs for exploitation of natural resources. Detailed mapping of vegetation and soils at the level of the lower taxonomic units is accomplished at medium and large scales. Figures 6; references: 26 Russian. [54-5303]

UDC 631.4:629.78

USE OF GOUDRIAN MODEL IN STUDYING LAWS OF REFLECTION IN VEGETATION-SOIL SYSTEM IN OPTICAL RANGE. II. INFLUENCE OF ILLUMINATION CONDITIONS ON SPECTRAL BRIGHTNESS COEFFICIENTS

VYGODSKAYA, N. N. and GORSHKOVA, I. I., Geography Faculty, Moscow State University imeni M. V. Lomonosov

[Abstract] The first part of this study (N. N. Vygodskaya, et al., ISSLED. ZEMLI IZ KOSMOSA, No 4, pp 61-70, 1984) gave the results of numerical experiments based on the Goudrian model (J. Goudrian, CROP MICROMETEOROLOGY: A SIMULATION STUDY, Wageningen, 1977, 250 pages). These results characterized the laws of change of the spectral brightness coefficients (b_λ) of the vegetation-soil system as a function of density (L) of the vegetation cover (VC), type of spatial orientation of phytoelements, spectral reflection and transmission coefficients (ρ_{ph}, τ_{ph}) of individual phytoelements (assuming $\rho_{ph} = \tau_{ph}$) and coefficients of spectral reflection of the soil (ρ_s) with sighting to the nadir ($\theta_0 = 0°$) and with a solar altitude ($h_\odot$) greater than 55°. In this second part of the study the authors give the influence of $h_\odot$ and S_λ/D_λ (S = direct, D = scattered radiation) on the spectral brightness coefficient in the visible and near-IR solar spectrum ranges with sighting to the nadir. Due to the invariance property (b_λ ($h_\odot$, θ_0) = b_λ (θ_0, $h_\odot$) with $S_\lambda \gg D_\lambda$) the laws of change of b_λ as a function of $h_\odot$ for the nadir are identical to the laws of change of b_λ as a function of θ_0 for the sun at the zenith. It was found that in the solution of inverse problems, the lesser the dependence of the spectral brightness coefficient on the VC canopy density, optical properties of the soil and individual phytoelements, the greater is the need for taking the influence of

illumination conditions on the spectral brightness coefficient into account. The spectral brightness coefficient should be reduced to values measured with an effective solar altitude 40-45°. The values of the reduction functions will be significantly dependent on canopy density and the spectral contrast determined by the coefficients of reflection for the soil and individual phytoelements. Figures 6; tables 5; references 10: 7 Russian, 3 Western.
[54-5303]

ANALYSIS OF MESOFISSURING ON SPACE PHOTOGRAPHS: NEW TECHNIQUE FOR STUDY OF PETROLEUM AND GAS DEPOSITS

AMURSKIY, G. I., ABRAMENOK, G. A. and SOLOV'YEV, N. N., All-Union Natural Gas Scientific Research Institute, Moscow

[Abstract] Zones of mesofissuring are linear (or in the case of their intersection by systems of a different strike, linear-focal) zones of reduced density, within whose areas increased fluid conductivity of rocks is ensured by a branched system of so-called tectonic channels of different scales from ordinary disjunctive dislocations to microfissures. On large-scale photographs these zones of mesofissuring can be discriminated in the form of zones of increased density of relatively short (0.5-4 km) lineaments with a width up to several kilometers and with a length of many tens of kilometers. They are characterized by the following: sustained orientation of individual elements; complex unambiguous relationship to known faults; nondependence on local plicative tectonics (the width of the zone of microfissuring frequently exceeds the dimensions of the folds; presence of systems of fissures of different morphology, such as stepped, sawtooth and echeloned arrangements). Since the formation of such zones results in the appearance of extended zones of intensive reduced density of rocks, their tracing and projection onto the level of productive strata can serve as a basis for solving important problems in study and exploitation of petroleum and gas deposits. Space photographs are the only tools which can be used in tracing these znes, in determining such parameters as azimuthal arrangement, extent, degree of concentration and grouping. Only remote materials objectively reflect the morphology of elements of the most recent stressed state of strata imprinted in the surface horizons. The first attempts at using such data in planning the development of petroleum and gas condensate deposits have given encouraging results. The authors stress that reliable and positive results can be obtained by this method only when used in combination with the results of traditional geological and geophysical research. References 11: 10 Russian, 1 Western.
[54-5303]

MINIMIZING INFLUENCE OF EARTH'S CURVATURE IN PROJECTIVE RECTIFICATION OF
SPACE PHOTOGRAPHS INTO PHOTOPLANS AND PHOTOMAPS

KUZINA, A. M., RAMM, N. S. and SKORODUMOV, A. P., Aerial Methods Laboratory,
Aerogeologiya Geological Production Association, Leningrad

[Abstract] The geometrical correction of space photographs required for
their rectification into photoplans and photomaps in a particular projection
is usually accomplished without allowance for local relief and involves
elimination of the influence of tilt and the earth's curvature. In this
article it is shown that this correction can be considerably simplified by
replacing the coupling of space photograph coordinates and the photoplan
(photomap) by a projective (linear-fractional) dependence. Such a replacement
makes it possible to rectify space photographs on standard photorectifiers.
It also makes possible a sharp increase in the efficiency of digital rectifica-
tion of space photographs. It has been stated that in virtually all cases
these procedures would result in a considerable decrease in the accuracy of
the compiled maps of plans. In this article the authors demonstrate that
with an effective choice of the projective correspondence the residual errors
are decreased by several times and accordingly there is a broadening of the
field of application of projective rectifications of space photographs. The
following cases are examined: rectification of medium- and large-scale space
photographs into photoplans at 1:500,000-1:100,000; rectification of medium-
scale photographs into photomaps at 1:2,000,000-1:200,000; rectification of
large-scale oblique photographs into photoplans at 1:100,000-1:50,000.
Formulas are derived for computing the optimum rectification plane. A table
of residual errors is given. The optimum choice of the rectification plane
makes possible a considerable decrease in geometrical distortion of the space
image caused by the earth's curvature. Figures 2; tables 1; references 5:
4 Russian, 1 Western.
[54-5303]

SPACE POLICY AND ADMINISTRATION

FORECASTS ON LONG-RANGE DEVELOPMENT OF SPACE PROGRAMS

Moscow KRYL'YA RODINY in Russian No 11, Nov 84 pp 16-17

[Article by V. Senkevich, doctor of technical sciences, chairman, "K.E. Tsiolkovskiy and Scientific Prediction" Section, Annual Tsiolkovskiy Scientific Lectures: "On the Threshold of a New Millennium"]

[Text] On 2 October 1984, after completing their program of scientific and technical investigations and experiments on board the "Salyut-7"-"Soyuz T-11" orbital complex, cosmonauts Leonid Kizim, Vladimir Solov'yev and Oleg At'kov returned to Earth. The longest manned flight in history--237 days--had just been completed.

Never in the history of world science and technology was there a branch that has been developed as rapidly as cosmonautics. Several thousand automatic devices have already been placed in near and outer space, following the path broken by the first Soviet artificial Earth satellite in 1957. Following the first cosmonaut in the Universe, Yu.A. Gagarin, a citizen of the Union of Soviet Socialist Republics, representatives of 15 countries--including all the countries of the socialist concord--have visited the heights beneath the stars. Our country's successes in conquering space embody the huge social, economic, cultural and scientific transformations carried out by the Soviet people after the Great October Socialist Revolution, the 67th aniversary of which is being marked these days by all progressive mankind. Our people are proud of the fact that they were the first to open the epoch of socialism and the first to tread the road into space. They have proven that they are capable of the boldest plans and daring, and that the path pointed out by Lenin is is the only correct path to prosperity and power.

Near-space has become an arena of ever-increasing activity by people. Both automatic and manned spacecraft of different types and for different purposes fly in it. And the direction this work is taking and will take is of vital importance.

The course toward the military use of space taken by the imperialistic circles in the United States is causing alarm and indignation in the world. In defiance of international agreements, R. Reagan's administration is setting out to create different types of space weapons and an antisatellite system. There

are reports about Washington's program for the militarization of space that has been developed and is already being carried out. In 1982, the United States Air Force declared openly the creation of a space command. About 100 American artificial Earth satellites are already in near-Earth orbits for military purposes. In the next 5 years alone, the U.S. government plans to spend more than $25 billion for preparations to conduct "star wars." A special space center for the launching of reusable ships for purely military purposes is being built hastily near Point Arguello, California. Incidentally, with the agreement of the Reagan administration, the Pentagon has "reserved" for itself more than one-third of all the flights of those spacecraft.

Against this background of a military rush into space, the unchanged course of the Soviet Union, the countries of the socialist concord and other peace-loving nations for the use of space in the interests of human progress and for the good of the people on the planet Earth is even clearer and more convincing.

A new and convincing proof of the noble purposes of the Soviet space program, the high level of our space technology, and the skill and bravery of our cosmonauts is the flight of Leonid Kizim, Vladimir Solov'yev and Oleg At'kov, which was completed on the eve of the Great October holiday. They set a new record for the duration of a flight in space. The work of the main crew of the "Salyut-7"-"Soyuz" orbital complex and the visiting expeditions, including a Soviet-Indian one, increased the glory of the country of the October revolution, which opened the road into space and revealed new horizons in the conquest and peaceful use of space.

"Our space program, both national and international," emphasized the general secretary of the CPSU Central Committee and chairman of the Presidium of the USSR Supreme Soviet, K.U. Chernenko, "is a peaceful one. We turn to the peoples of this planet again and again: let us together, and communicating, conquer space in the name of human happiness and in the name of a better life for future generations!"

Priority to Modular Complexes

People are becoming more and more interested in the future of cosmonautics. It captures the imagination, people dream about it and they figure it out, using brand new prediction methods and the statistics from past years. Right now there are hundreds of diverse mathematical methods, techniques, scientific and technical prediction models, and plans for future spacecraft that make it possible to carry out this work extremely effectively and on a high scientific level. The future of world cosmonautics is discussed every year in Kaluga, where K.E. Tsiolkovskiy lived and worked.

What, in the opinions of domestic and foreign scientists, does cosmonautics offer in the next 20-30 years?

According to the predictions, for the end of the 1980's and the 1990's, the development of modular-block spacecraft is assumed. They will then be used as the basis for the construction of large, multipurpose orbital platforms. Each platform, with its standardized on-board systems and equipment, will make it

possible to solve a whole complex of problems in the interests of various consumers, which will increase the object's effectiveness and the time of its active existence. By that time the designers will obviously provide a capability for repairing platforms under orbital flight conditions, and probably reusable means for injection into orbit, including launch vehicle stages that are recovered, for example, after they are lowered by parachutes. The problem of returning the most expensive on-board equipment--optical telescopes, some types of radio and infrared equipment, elements of precision control systems and so on--will apparently be solved.

The process of microminiaturization of the on-board equipment, instruments and service systems will continue. All of this will reduce the total cost of lifting a useful load into space.

Even now, cosmonautics is called a catalyst for science and technology. This definition will become even more correct for cosmonautics in the future. Developments in rocket and space technology are "speeding up" the development and improvement of branches that are interrelated with it, with particular emphasis on power engineering, the study of materials, communications electronics, instrument building, optics and computer technology. In the opinion of many scientists, the terms "spaceification of technology," "spaceification of science" and "spaceification of production," which have just entered our lives, will become the norm and the program of action for very many branches of science and technology in 15-20 years.

Capital Mastery of Near-Earth Orbits

In the opinion of many scientists, the main types of rocket and space technology used in near space will be general-purpose automatic and manned space platforms and multipurpose complexes, as well as permanent, manned orbital stations and facilities for transporting cargoes to them and maintaining them (such as the contemporary "Soyuz," "Progress" and "Cosmos-1443" ships).

Other fields for significant development will be space communication, meteorology, navigation, geodesy and environmental monitoring and protection systems, as well as systems for searching for the crews and passengers of ships and airplanes that have suffered calamities, plus others. By the 1990's, new meteorological satellites that have been introduced into the international system will be able to supply specialists with data for reliable weekly and possible longer term weather forecasts. This will make it possible to determine the times for agricultural, construction and other types of work more accurately and, according to the scientists' calculation, will produce a tangible economic effect. Space television will be raised to a higher technical level. Satellites carrying high-powered transmitters will make it possible to receive television signals on the home antennas of television sets everywhere.

Space production should be placed on an industrial basis. Space stations that are plants for the industrial production of new materials will apparently be in operation at the beginning of the new millennium. The weight and size of orbital stations assembled in space will increase, along with the size of

their crews, the time of their active existence and the number of docking units. Specialists from different countries think that the stations themselves will consist of a large central module in which the crew will live and mooring units for docking with transport ships that are attached to the central unit, or independent modules for the performance of various types of work (astronomical, power engineering, medical-biological and space technology modules, among others).

What will such a space complex look like?

Imagine the future "K.E. Tsiolkovskiy" orbital station, assembled from individual large sections and modules and serviced by transport ships with increased cargo capacities. In the center of the complex there is a very large flying vehicle with several docking assemblies and airlock compartments. The crew members systematically exit through them into open space in order to inspect the station and to deliver to it the results of investigations performed in the attached sections and modules.

Since the "K.E. Tsiolkovskiy" station is designed to function for a long time, a significant part of its scientific and service equipment is removable. This makes it possible to replace it with new and improved equipment that is delivered from Earth by transport ships. Repair and maintenance of the on-board service systems is made easier. In the station and the attached units and modules, the crew does not restrict itself to scientific research and experiments alone. Using the unique properties of the space environment, the crew makes new chemical and biological compounds and various materials with properties that are programmed ahead of time and that can be produced only under conditions of weightlessness and vacuum. Ready-made superpure metals, special types of glass, pharmaceutical preparations, crystals for radio engineering that are grown from melts--all these things are delivered to Earth by the transport ships.

Orbital scientific and production complexes are already moving out of the realm of fantasy and becoming the subject of various scientific research and experimental design work. On the basis of calculations that were made, a group of foreign specialists arrived at the conclusion that the total value of crystals grown in spacecraft every year could reach $325 million. Other specialists think that the production of various superpure medical preparations may be more efficient and economically profitable and useful for people. In general, a transition to the industrial production of valuable substances in space is one of the important predicted areas for improving the effective mastery of near-Earth orbits for peaceful purposes, in the interest of progress for all mankind.

The Moon: a Scientific and Production Base

That nocturnal beauty, the Moon, will continue for many more years to be an important object of study and a unique scientific and technical testing ground for the thorough checking of engineering solutions found by the developers of space technology. With the placement on the Moon of a permanently active automatic service, it will be possible to make systematic measurements of

cosmic radiation, corpuscular flows and other phenomena that are distorted near Earth by its strong magnetic field.

In the longer view, on the Moon we can build various automated technical structures, laboratories and plants for the production of materials that are difficult or impossible to produce under terrestrial conditions. True, such work is being predicted primarily for no sooner than the third millennium, when a new generation of space technology equipment will appear.

The basis of the extensive mastery of the Earth's natural satellite can be manned stations in a selenocentric polar orbit or, as has been suggested in one hypothetical plan, a pit created on the Moon that contains an electromagnetic unit for the delivery of materials from its surface into near-Moon and then near-Earth orbits. According to calculations, the cost of such a delivery of materials for the builders of objects in near space is less than the cost of their delivery from Earth by a factor of 20. From the Moon it is possible to obtain oxygen, silicon, iron, calcium, titanium, aluminum and magnesium, all of which make up the basic content of its rocks. The creators of the plan think that a total of 150 people working on the Moon will be able to extract and deliver up to 1 million tons of lunar rock into near space every year. They will first be sent to a libration point[1] behind the Moon at a distance of about 80,000 km, then to orbital stations at the libration point between the Moon and the Earth. There they will be smelted for the extraction of substances needed for the construction of objects in space.

Into Deep Space

Deep space has also not escaped the attention of those making predictions. They think that in future years the study of the planets, heavenly bodies and interplanetary space in the Solar System will be carried out more intensively. This will make it possible to solve, still in this century, a number of fundamental problems related to the origin and evolution of the planets and their atmospheres, magnetic fields and other phenomena. The scales and volume of the work done by automatic interplanetary stations will be enlarged.

New automatic envoys to Venus and Mars will carry out radar studies and map the surfaces of these planets. Some scientists think that the establishment of balloon-type probes drifting in Venus's thick atmosphere is one of the earliest goals of space technology. The delivery of soil from Mars and other heavenly bodies is also on the agenda. Other predictions involved the landing of descent vehicles on the asteroids or Mars's satellites (Phobos or Deimos) and the photographing of comets at close range (for example, the passage of Halley's Comet close to the Sun is expected in February 1986).

As scientists think, these assignments can be carried out by domestic and world cosmonautics as early as the near future. But in what sequence, and which ones should be given preference? Opinions differ about this.

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[1]A libration point is the point at which a heavenly body that is moving under the influence of two other bodies of significant mass can be in a state of relative equilibrium with respect to these two bodies.

The plan of a motorized glider capable of flying in Mars's rarefied atmosphere is a matter of definite interest. The glider will be delivered, in folded form, to the region to be investigated by the descent vehicle of an automatic interplanetary station. At an altitude of about 15 km about the planet's surface, disengagement will take place and the glider will begin its independent flight. According to the plan of the specialists who developed it, this folding "Mars plane" (it will weigh 100 kg, have a fuselage 6.35 m long and a wingspan of up to 21 m), which will be fitted with a light gas-powered engine and a propeller 3.4 m in diameter, will be able to fly over the planet for up to 10,000 km in 17-25 hours.

There are already quite a few plans for future automatic spacecraft that have been developed in different countries. However, no matter how close to perfection these automatic envoys may become, they cannot be used to unravel all the mysteries of deep space. There will come a time--and it is apparently not that far in the future (in 50-100 years)--when man himself will be able to stand a working watch in different corners of the Solar System. He will be capable of placing both near and deep space at the service of progress.

In order to realize this noble purpose, peace is needed. Resoluteness and the will of the peoples of all countries are needed right now, in order to suppress in its incipiency the attempts of the imperialistic circles in the United States and thos of like minds to transform space into an arena of war. The reason of millions must vanquish the folly of the haters of mankind. In contemplating the paths of development of cosmonautics and the conquest and utilization of space, most prognosticators believe in a bright and peaceful future for the people of planet Earth.

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U.S. SAID TO SEEK MILITARY ADVANTAGE IN SPACE

Moscow ZEMLYA I VSELENNAYA in Russian No 5, Sep-Oct 84 pp 6-11

[Article by V. S. Avduyevskiy, academician: "Space Should be Peaceful"]

[Text] An arms race in space is a monstrous, exceedingly dangerous senseless course of action favoring the unleashing of nuclear war and annihilation of all the achievements of human civilization and life itself on the earth. In this last quarter of the 20th century, as never before, mankind is faced with a dilemma: to be or not to be!

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Man, His Terrestrial Environment and Space

Man is part of the earth's biosphere. Everything that we have today, oxygen for breathing, the ozone layer which protects us from hard ultraviolet rays, food products and climate, ensuring us conditions for life, all this is the product of a unique "factory" for the assimilation of solar energy -- the biosphere created by nature.

And even when other energy sources will be used everywhere, such as the energy of controllable thermonuclear reactions or the earth's internal energy, and we have learned how to transform solar energy directly, more efficiently, we still will be unable to separate ourselves from the living nature around us. For the time being precisely it ensures equilibrium on the earth, annihilating waste, reworking decomposition products and returning them to the ecological cycle, without which mankind would perish in its own debris. Man is evolving together with all living nature and scarcely ever can he truly isolate himself from it, and indeed, it is undesirable to attempt seriously to do this.

It is impossible to forget about this now when man has begun to exploit a new realm of activity, space, which is not a part of the biosphere, although space undoubtedly exerts an influence on it. It is precisely man who will govern what space will become after its mastery and how this mastery will exert an influence on terrestrial life, its evolution and the development of civilization.

Now we know that space is by no means a void. Space is full of radiant energy, only a small part of which is assimilated by the earth. In addition to energy, radiation carries an enormous amount of information concerning the universe which is inaccessible here on earth, beneath the atmospheric screen.

Space Research Continues to Progress

Flights into space have become a new step in the development of human civilization and at the same time a qualitative jump in man's knowledge of himself. Glancing at the earth from a distance, becoming more familiar with the moon, the planets and the entire solar system, man has begun to think in categories which earlier were not included among ordinary terrestrial concepts.

The level of civilization is now such that the influence of economic activity on nature, on the biosphere, and accordingly, the conditions for life on earth, is very great. However, man lives in a definite social environment and his life is more and more dependent on advances in civilization. Its development is related to the growing use of natural resources on the earth and therefore the regulation of this process is now a problem of enormous importance.

Space vehicles ensure a rapid and global study of the earth's natural resources, geological exploration and the search for minerals; they make it possible to determine the condition of forests, agricultural lands, discharge of rivers and state of glaciers. At the same time, space is providing ideal conditions for monitoring the biosphere. An important condition for this is the monitoring of the preservation and purity of the atmosphere. Together with meteorological investigations, monitoring of the environment will make it possible to detect in time dangerous consequences for economic activity and to take the necessary measures.

Enormous changes in man's life can be anticipated in connection with the development of satellite communication systems. The scientific knowledge accumulated by man, his cultural attainments and the most significant advances in social and scientific-technical development, all this should be readily accessible to each individual person. The sole method which can ensure the rapid transmission of data to all users is via satellite. Such specialized communication satellites, situated at different points in circumterrestrial space and in a geostationary orbit, cover enormous territories, have an enormous transmission capacity and ensure the routine exchange of information. In its significance for progress the "information" era which has begun will be comparable to the era of electricity.

Manned flights into space were the pinnacle of success in rocket-space technology. The range of cosmonaut tasks is exceptionally diverse: astrophysics, space technology, study of the earth's natural resources and the earth's atmosphere and technical experiments. Particular attention is given to biomedical research, as a result of which the possibility of man's prolonged presence in a state of weightlessness was demonstrated, as well as his successful work there, in space vehicles with artificial life support. However, cosmonauts are supplied from earth with the necessary expendable products, that is, they remain tied to the earth and its biosphere. In my opinion such a situation will persist for a long time to come and apparently for the time being there are no adequate arguments for creating completely closed ecological systems on space vehicles.

The agenda calls for the industrialization of space, the joint development of productive forces in space and on the earth, the development of enormous space

supersystems, manned stations and space "factories." International cooperation will be of great importance in this work. Space vehicles fly over all countries and international cooperation in their use favors cooperation on the earth.

Space Belongs to Everyone

"...We are mastering space on a planned basis," stated Comrade K. U. Chernenko, General Secretary of the Central Committee CPSU, Chairman of the Presidium, USSR Supreme Soviet, when presenting awards to the Soviet cosmonauts V. A. Lyakhov and A. P. Aleksandrov. "And at the same time we insist that it be used exclusively for peaceful purposes, for the welfare of all mankind. Space must be peaceful!"

However, there are people on earth who nuture other plans for the exploitation of space. The United States has declared its intent to transform space into an arena of war and to initiate a space arms race.

History bears witness that the development of science and technology in all eras has been used invariably for improving the means of warfare and for the annihilation of people. Weaponry has now been scattered over the entire earth, on the seas and oceans, and air space has been transformed into an arena of activity of bombers and fighters.

The development of rocket-nuclear weapons and other means capable not only of annihilating many hundreds of millions of people, but also completely obliterating individual countries from the face of the earth and annihilating life itself on the earth or setting mankind back tens and hundreds of thousands of years, was fundamentally new after 1945. Under conditions of the explosive international situation it is very important not to broaden the sphere of use of new armaments and not to place them where there are none now. Space is such a medium. There are no boundaries between countries there and all countries consent that space vehicles fly over their territories. Thus, all the necessary conditions for keeping space peaceful are present and there are no objective preconditions making negotiations on this matter difficult.

The Soviet Union is proceeding on this basis, consistently pursuing a peaceful policy and on a unilateral basis assuming the obligation not to launch any type of antisatellite weaponry into space as long as other countries refrain from doing so. Due to the efforts of the USSR and the socialist cooperation countries, supported by a number of peace-loving states, it has been possible to conclude international agreements partially restricting the military use of space. However, existing international accords of this type for the time being still do not cover some important aspects of space activity and leave loopholes for putting weapons into circumterrestrial orbits. For this reason the Soviet Union has advanced new proposals for forestalling the militarization of space. A resolution examined at the 38th Session of the UN General Assembly is of particularly great importance. This resolution contains a draft agreement on the banning of the use of force in space and from space, directed toward the earth, a resolution sponsored by the Soviet Union. The resolution was approved by the overwhelming majority of UN member countries and the draft

treaty was sent for discussion by participants on the Disarmament Conference. Only the United States, left by itself, voted against the draft agreement.

Strategy of Adventurism

For many years now the military clique in the United States has sought an opportunity for breaking the strategic parity established in the world. Space has not escaped their attention. The successes in the exploitation of space, on which most of the world's peoples lay their hopes for progress and for improving life on earth, are met in the United States by ever-greater use of space for military purposes.

First military-applied space systems were developed for supporting the activities of United States armed forces on the earth. American reconnaissance, communication, meteorological and navigation satellites were constantly used by the Pentagon during the aggressive war in Vietnam. The United States supplied reconnaissance information to Great Britain duing the time of the Falkland Islands military conflict (ZEMLYA I VSELENNAYA, No 2, p 14, 1984 -- Editor's Note).

However, the use of satellites only for the support of military operations on the earth no longer satisfies the military clique in the United States, actively supported by the military-industrial complex. Due to the increasing dependence of the United States armed forces on space facilities, especially at numerous bases situated everywhere on the earth, in 1982 the Reagan administration established a special space command and issued a special directive on the development of work on the militarization of space. The United States is now completing development of an antisatellite system for combatting with satellites which employs a two-stage rocket with a self-guidance head, launched from F-15 fighters.

The Pentagon is giving great importance to the "Space Shuttle" system developed in the United States. This system, advertised as the cheapest transport vehicle for putting satellites into orbit, for the time being in actuality is very expensive. The use of a shuttle ship as a manned station with an operating time of 7-8 days is inefficient for the solution of scientific problems.

But none of these considerations are of importance for the Pentagon, which has an astronomical military budget. In the opinion of American military specialists, shuttle ships will be necessary in developing and perfecting qualitatively new types of space armament, including lasers of different types. Laser weapons, according to American militarists, are most effective and will find their primary application in space, since outside the atmosphere they have considerable effective range. In the American plans shuttle ships are also intended for the rapid deployment of systems in space consisting of a great number of combat strike vehicles. For this purpose the United States is developing freighters of the "Space Shuttle" systems, including those for single-time use, when cargo with a mass of up to a hundred tons is placed on the booster-rocket instead of a shuttle ship.

In his speech of 23 March 1983 President Reagan declared his determination to develop a broad-scale system of antimissile defense, deployed on earth and in space, calling it "a future which promises hope." For this purpose hundreds of satellites should be put into orbits around the earth. These would be supplied with ray and other types of "third generation" weapons which would be capable of damaging ballistic missiles in the boost segment. But some specialists are already cautioning: it would not be possible to destroy all the missiles being launched because there are already such great numbers of missiles armed with nuclear weapons that even a small percentage of them would inflict irreparable losses.

Nevertheless, plans for establishing an antimissile defense system in the United States are becoming more and more real. In 1983 a group of military and scientific specialists worked out a program providing for development of prototypes of ray weapons for space systems by 1989 and President Reagan validated these plans in January 1984 in his directive No 119, allocating, according to data in the American press, 27 billion dollars for the next five years. It should be emphasized that the true direction of all these plans is far from "defensive purposes." The concept of militarization of space has nothing in common with peaceful purposes.

Fictitious Supremacy

The obvious fallacy of the American concept based on the striving to acquire for itself unilateral advantages due to supposedly existing "technological superiority" is tied-in with a constant underevaluation of Soviet scientific and technical potential by American experts.

It is useful to turn to history. For example, in 1945 the Soviet Union made a proposal to ban nuclear weapons. The United States, sure that the Soviet Union, ravaged by the war, would not be able to produce an atomic bomb sooner than after 15-20 years, shoved this proposal aside. But despite the predictions of American specialists, the USSR had already produced an atomic bomb in 1949.

In the early 1970's the United States outfitted its intercontinental missiles with separable warheads so that a single missile became capable of hitting several enemy missiles. This was done against a background of propagandistic speeches about an exchange of "limited strikes" and a "counter force," so that missiles with separable warheads were virtually proclaimed a "weapon of peace." The USSR rapidly restored the balance, also putting missiles with separable warheads in its arsenal. Not counting on this, American politicians declared the restoration of strategic parity to be a "destabilizing" factor. The same thing is being repeated today.

The Soviet Union is maintaining vigilance and having enormous scientific and technical potential will never allow the United States to have supremacy in space.

The government of the Soviet Union has waged and will continue to wage a fight against the militarization of space. This struggle is in full accord with the entire peaceful policy of the USSR, the entire struggle of our country against

the use of nuclear weapons, for a universal freeze on nuclear potential, for a total cessation of nuclear tests and for the declaration of Europe to be a territory free of nuclear weapons.

The movement against nuclear arms in the world is growing and gaining strength. Hundreds of thousands of people are taking to the streets and speaking out against the placement of American cruise missiles and the "Pershing-2" in Western Europe and the transformation of Western Europe into a nuclear hostage of the United States. Some cities in Europe have declared themselves nuclear-free. Bearing in mind the enormous political and moral significance of the mass demonstrations of the workers for peace, the partisans of peace even now must unleash a struggle on still a broader scale against the new sinister plans threatening the destruction of mankind. Projects for the placement of weapons in space occupy a special place in such plans.

Scientists, engineers, public figures, historians and journalists concerned with the subject of exploitation of space and all supporters of the peaceful development of space must explain to the people the danger of the American policy in space. In this explanation to the people it is highly important to clarify those aspects of the arms race which are especially glossed-over or omitted in the propagandistic and demagogic speeches of western political and military leaders. The fact is that if the intentions of the American administration to initiate a space arms race are realized, the threat of destruction will hang over mankind in both the figurative and literal sense of the word. An arms race in space will "bury" many, if not all peaceful space programs. Whereas the presence of military aircraft, ships and submarines with missiles on the earth has not resulted in a cessation of peaceful commerce, the situation is different in space. Earth satellites fly over all countries, there is no "territorial" space, no specially allocated corridors in space for flight: in general there are not and cannot be restrictions. As a result, many hundreds of space launching platforms with death-dealing weapons will be constantly revolving about the globe over all countries, seas and oceans. No one on earth will be able to feel himself safe and no one will know with precisely what weapons these space vehicles are outfitted. With the deployment of space forces there will be an inevitable increase in the probability of an accidental outbreak of nuclear war because there is simply no time to spare for evaluating the circumstances when some space vehicle malfunctions and a spurious signal warning of an attack is received.

Antimissile defense space weaponry will evidently be very complex and the main systems will require prolonged testing in space. Accordingly, if there are agreements banning the launching of weapons into space the monitoring of what is going on is still entirely possible. However, after the placement of any military systems in orbits any agreement on the demilitarization of space in actuality will become many times more difficult and may possibly be completely unattainable.

The cessation of peaceful activity in space will be a step backward, a gloomy page in the history of mankind. But precisely now there is still a possibility for seeing to it that this page in history is never written.

People are aspiring to distant journeys in space, to the planets, to the stars, but all the same, one way or another, they will return to the earth... It is still not too late to stop the slipping toward the nuclear abyss. The Soviet people, the peoples of socialist cooperation and all honorable people on the earth are convinced: in the end reason will prevail and man will not take the way of self-annihilation.

5303
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MILITARY JOURNAL ON U.S. INTELLIGENCE SATELLITES

[Article by Col (Reserve) N. Gavrilov, candidate of military sciences]

[Text] The new round in the arms race that was started by the present U.S.
administration has been embodied in the militarization of near space. As the
foreign press has reported, in a directive dated 7 July 1982 and entitled
"U.S. National Policy for the Next Decade in the Field of the Conquest of
Space," President Reagan proposed, as one of the United States' primary goals,
the strengthening of its military might by the development of space weapons,
as well as the achievement of supremacy in the conquest and utilization of
space. In particular, this directive to the Department of Defense sanctions
it "to undertake actions in space to support our right to self-defense," to
insure "regularity of access" to space, and to achieve "a high degree of oper-
ational readiness, viability and security of the space facilities needed for
the national space system." The performance of the following tasks was as-
signed to military space facilities in the directive: control and communica-
tions, observation, warning, navigation, registration of the state of the en-
vironment, defense. The U.S. administration recently adopted the course of
the extensive utilization of space for the placement of advanced weapons, in-
cluding weapons for combat with ISZ's [artificial Earth satellite] and for in-
flicting strikes on terrestrial targets, as well as for the organization of a
PRO [antimissile defense]. All of this is indicative not of the defensive,
but of the aggressive purposes of the militarization of space being undertaken
by the American government.

Judging by reports in the foreign press, in the United States' military activ-
ities in space an important place is given to observations from spacecraft
(KA) of foreign territories--primarily the USSR and the other countries of the
socialist concord--and the world ocean, conducted by the intelligence services
in the Pentagon's interests. This has been confirmed by statements from sev-
eral American officials. For instance, in 1980 the Secretary of the Air Force
stated that in the next 10-15 years, the United States' military space program
will be largely subordinated to the solution of three basic problems: obtain-
ing information about regions where armed conflicts have arisen; reducing the
vulnerability of its own strategic forces by means of early warning and the
establishment of the nature of the measurements taken by an enemy; monitoring
the development and deployment of new weapons systems by a probable enemy.

The United States' military space activity began in 1956, when Lockheed built visual surveillance facilities for the observation of the territory of foreign nations. The exceptional interest of the American military and political leadership in space surveillance, which appeared at the very dawn of their activities in space, was the result of such special properties of it as the global nature of the observations, unimpeded flight above any section of foreign territory, the possibility of surveying a given region or object in a comparatively short period of time, and the high degree of periodicity and timeliness of the conduct of surveillance, including the possbility of conducting it on a time scale that is close to real. At the present time, as the Western press has noted, surveillance facilities play the leading role in the United States' arsenal of space weapons: of 18 national systems used for military purposes, 9 are intelligence systems. The percentage of satellites for this purpose is 70 percent of all the spacecraft placed in orbit before 1983.

The obtaining of data with the help of spacecraft occupies an important place in the activities of the United States' intelligence services. Particular attention is given to surveying a probable enemy's strategic facilities (observation of their development, production and deployment), as well as the use of KA's in the interests of planning nuclear missile strikes. From the beginning of the 1970's, space facilities began to be used extensively for observing the situation in those regions of the world where so-called "conflict situations" have arisen. In the future, the United States' military leadership intends to create a battlefield space surveillance system that is also capable of indicating targets for weapons systems in both land and sea TVD's [theater of operation].

According to the American classification, there exist four types of surveillance spacecraft that are used for observation of the territories of foreign countries and the world ocean for military purposes: visual surveillance (images of objects and situations are produced); surveillance by means of comparing the radiation spectra of observed objects with standard spectra; surveillance of the emissions of radio facilities that are part of weapons systems and military technology; integrated surveillance using data-gathering equipment, the functioning of which is based on various physical principles. Of these types, the ones developed most extensively were facilities for visual surveillance and the surveillance of radio emissions. It has been noted that from 1960 to 1983, the United States sent into orbit about 300 intelligence KA's, of which about 210 were intended for the conduct of visual surveillance, 70 for radio surveillance and about 20 for integrated surveillance.

Below we present information about U.S. space surveillance facilities that are now in existence, are being modernized, or are being developed, as well as information about KA's for investigating natural resources that are carrying out assignments related to economic and engineering intelligence.

According to reports in the foreign press, spacecraft for the conduct of visual and integrated surveillance belong to three departments: the Air Force (Samos-M and (Lasp)), the TsRU [Central Intelligence Agency] (KH-11) and NASA [National Aeronautics and Space Administration] (Landsat). Despite the departmental division of the affiliation of the KA's, there is an active exchange of information between the Department of Defense's and the CIA's

intelligence arms, and the data obtained from the Landsat spacecraft by NASA are presented to both the Department of Defense and the CIA.

Samos-M is used to survey objects of a strategic and tactical-operational nature for the purpose of a detailed determination of their tactical and technical characteristics and the special features of their functioning. It has been mentioned that in recent years this spacecraft has also been used to survey regions in which critical situations have arisen. The present modification of the Samos-M--the E-6--has been in use since 1969. In all, about 100 satellites for detailed visual surveying have been launched, of which about 50 are the E-6 model.

As an example of the special-purpose equipment installed in KA's, there is the long-focus aerial photography equipment (AFA), which under optimum conditions provides geographic resolution of up to 15 cm, which--in the opinion of the American experts--makes it possible to identify and determine forms reliably and to evaluate the dimensions of almost all important military objects (see table on next page). It is assumed that the Samos-M's intelligence capabilities can be improved by the use in the AFA of multizonal and anticamouflage photographic materials, which make photographs of low-contrast and camouflaged objects hidden by traditional methods quite intelligible. Stereoscopic photography can be used for the better identification of objects and the determination of their characteristics.

Samos-M spacecraft are launched by Titan-3B launch vehicles into an orbit with a perigee altitude of 125-140 km, an apogee altitude of 330-415 km, and an orbital inclination of 96.5°. In order to prevent early descent of the KA from orbit and to achieve its best productivity, altitudinal maneuvering of the spacecraft is carried out. The altitude at which photography is carried out is sometimes reduced to 110 km in order to obtain high image resolution. The period of active existence of this KA can reach 160 days. The exposed film is delivered to Earth in special capsules that separate from the KA and enter the atmosphere with the help of their own descent engines. After braking a parachute system is triggered and the capsule lands in the vicinity of the Hawaiian Islands, where it is picked up in mid-air by specially equipped C-130 airplanes.

The Samos-M is considered to be obsolete at the present time. There are still several KA's that are in reserve and have not been launched.

The Lasp (or Big Bird) is used for visual coverage and detailed photographic surveying in the visible band of the spectrum and for obtaining radio intelligence. There have been reports that these KA's have been used to survey sea TVD's, as well as regions in which critical situations have arisen. In the period 1971-1983, a total of 18 Lasp craft were launched.

The spacecraft's hull and the main part of the service equipment were created under the MOL (military orbital manned laboratory) program, work on which was halted in 1969. According to the plan, an MOL laboratory should weigh 14 t, have a volume of 28 m^3, and have a time of active existence of up to 9 months.

Requirements of U.S. Air Force's Intelligence Service for Geographic Resolution of Images Obtained by Aerospace Intelligence Facilities

Объекты разведки (1)	Разрешение, требуемое для решения следующих задач разведки, м (2)				
	Обнаружение и распознавание класса объекта (3)	Установление типа объекта (4)	Распознавание известного образца оружия и боевой техники (5)	Выявление контуров, размеров и компонентов объекта (6)	Анализ состояния объекта (7)
Позиции баллистических ракет (включая МБР)(8)	3	1,5	0,6	0,3	0,075
Ракеты и артиллерия(9)	0,9	0,6	0,15	0,05	0,013
Компоненты ядерного оружия(10)	2,4	1,5	0,3	0,025	0,013
Транспортные машины и танки(11)	1,5	0,6	0,3	0,05	0,025
Войска на марше и привале(12)	6	2,1	1,2	0,3	0,075
Самолеты(13)	4,6	1,5	1,9	0,15	0,025
Аэродромные средства(14)	6	4,6	3	0,3	0,15
Радиолокационные станции(15)	3	0,9	0,3	0,15	0,013
Радиосредства(16)	1,5	0,3	0,15	0,15	0,15
Штабы и пункты управления(17)	3	1,5	0,9	0,15	0,025
Местность(18)	—	91	4,4	1,5	0,15
Побережье и места высадки десантов(19)	30	4,5	3	1,5	0,75
Минные поля(20)	9,1	6,1	0,9	0,025	—
Автомобильные дороги(21)	9,1	6,1	1,8	0,025	0,15
Железные дороги и сооружения на них(22)	30	15	6	1,5	0,6
Мосты(23)	6	4,5	1,5	0,9	0,3
Города и поселки(24)	60	30	3	3	0,3
Порты и гавани(25)	30	15	6	3	0,3
Надводные корабли(26)	7,6	4,6	0,6	0,3	0,013
Подводные лодки в надводном положении(27)	—	6	1,5	0,9	0,025

Key:
1. Surveyed Object
2. Resolution required to carry out following intelligence assignments, m
3. Detection and identification of class of object
4. Establishment of type of object
5. Identification of known type of weapon and military materiel
6. Determination of outlines, dimensions and components of an object
7. Analysis of status of object
8. Locations of ballistic missiles (including MBR's [intercontinental ballistic missile])
9. Missiles and artillery
10. Components of nuclear weapons
11. Transport vehicles and tanks
12. Troops, halted and on the march
13. Airplanes
14. Airfield facilities
15. Radar stations
16. Radio facilities
17. Headquarters and command posts
18. Terrain
19. Coast line and assault landing areas
20. Mine fields
21. Roads
22. Railways and structures on them
23. Bridges
24. Cities and villages
25. Ports and harbors
26. Surface vessels
27. Submarines on the surface

104

In order to carry out visual surveying, the Lasp is equipped with two AFA's and infrared equipment. The surveying photography is done with a camera made by the (ITEC) company that has a lens with a focal length of 61 cm and resolution of 180 lines/mm, which insures geographic resolution of at least 1 m from the standard flight orbits of the Lasp KA. The survey data are transmitted over radio links, for which purpose the film is developed while the satellite is still in flight. The Lasp KA's functioning is controlled (through the Air Force Control Center in Sunnyvale) by ground stations in Manhattan Beach (California) and Australia. These stations are also the main ones for the reception of operational information from the spacecraft.

Detailed photography is done with a camera made by the Perkin-Elmer company that has a lens with a focal length of 2.44 m. The best geographic resolution provided by the camera from typical orbital altitudes is 30-50 cm (the film has a resolution level of 400 lines/mm). The film is delivered to Earth in capsules (at least six are used during a single flight).

Lasp KA's are launched into orbit by a Titan-3D launch vehicle. Its orbital parameters are: altitude at perigee--150-180 km; at apogee--240-280 km; orbital inclination--96.5°. These craft have a better maneuvering system than the Samos-M, which increases their time in orbit (up to 262 days) and productivity.

At the present time the United States has several KA's that are considered to be obsolete.

The KH-11 "Keyhole" is used to conduct visual surveillance, with data transmission in digital form over a radio link (including relay satellites), which provides a high degree of timeliness of observation. The latter is also achieved by controlling the KA's functioning (observation modes) on a time scale that is close to real. The KH-11 craft have been used, for all practical purposes, since the middle of 1978. The first satellite was launched in December 1976, and at the end of 1983 there were five such craft in orbit.

The KH-11 weighs about 10 t. Its main structural feature is that for visual surveillance it does not use a photographic camera, but an electronic-optical system that has an operating principle analogous to that of the scanning radiometers used by the Landsat KA's to investigate natural resources. The image obtained by means of this system is formed on Earth, by special computers. The information transmitted from the KA is preliminarily recorded on Earth on magnetic tape.

In the foreign press it has been mentioned that the geographic resolution of the image that is formed is not quite as good as that of the images produced by the photographic equipment of the Samos-M and Lasp KA's, and is 1.5-3 m for most of the viewing band. At the same time, it has been reported that the companies manufacturing the KA and its equipment are working on improving the resolution of the operation and data transmission system to the level that has been achieved for modern photographic systems.

The KH-11 spacecraft are launched by Titan-3D rockets into orbits with a perigee of 240-280 km and an apogee of 500-750 km; the orbital inclination is
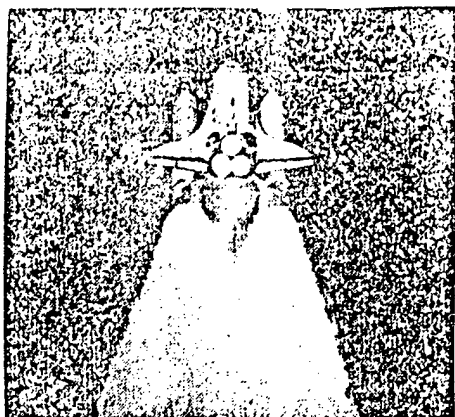
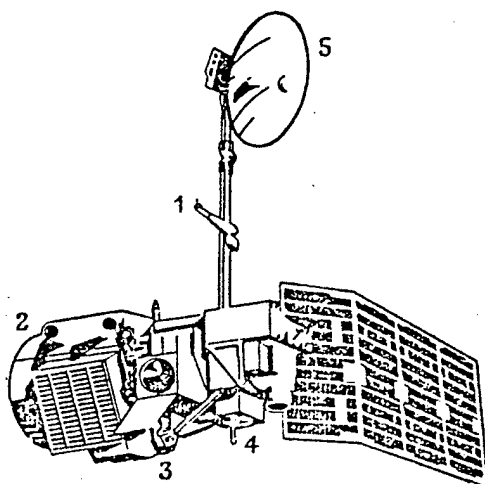Figure 1. Launch of the reusable "Shuttle" spacecraft.

Figure 2. Landsat spacecraft: 1. navigation system antenna; 2. detachable block with service equipment; 3. TM radiometer; 4. MSS radiometer; 5. antenna of system for transmitting data through a relay satellite).

96.9°. The times of active existence of the first three KA's were 716, 770 and 1,166 days.

In 1979 an announcement was made that the KH-11 spacecraft had begun to be improved. The modernized version will weigh more (up to 14 t) and should be serviced with the help of a transport system created on the basis of the use of the "Shuttle" reusable ship (Figure 1). Devices for refueling the KA in orbit are being developed for the purpose of increasing its time of active existence in orbit and improving its productivity. The possibility of equipping the modernized version with devices that will signal when it is exposed to a laser is also being investigated.

Landsat was developed and launched by NASA as an experimental operating unit for the purpose of testing the characteristics and design concept of a permanently acting national system for the remote investigation of natural resources known as LRSS (Land Remote Sensing Satellite System). Five craft have now been launched, with the last (Landsat-5) being launched in 1984 into an orbit at an altitude of 705 km (the first three were put in orbits at an altitude of 920 km, the fourth at 705 km).

The Landsat has a modular design (Figure 2). A modular block with service equipment is standard for most types of KA's in this weight class. It can be detached from the block with the information-gathering equipment and taken on board the "Shuttle" for repair, or it can be left in orbit if the block with the information-gathering equipment is to be repaired. Plans are being made to undertake the first recovery of the Landsat-4 KA in 1985, for which its own engine will be used to transfer it from its working orbit into the "Shuttle" ship's orbit. That ship will capture it with a manipulator and deliver it to Earth.

The information-gathering equipment on the first Landsat satellites was a multizonal television system consisting of three cameras with resolution of up to 4,500 lines (on the wave band 0.475-0.830 µm) and a four-channel MSS radiometer (0.5-0.6, 0.6-0.7, 0.7-0.8 and 0.8-1.1 µm). On the Landsat-4 and later

craft, the television system was replaced by a seven-channel TM radiometer with improved geographical resolution (30 m instead of the MSS unit's 70 m). It is used primarily for geological investigations on the wave bands 0.45-0.52, 0.52-0.60, 0.63-0.69, 0.76-0.90, 1.55-1.75, 2.05-2.35 and 10.4-12.5 μm. The radiometer's telescope is a Cassegrain unit and has a focal length of 2.4 m. Angular resolution in the visible and near-infrared bands of the spectrum is 42 μrad; in the middle and far infrared it is 44 and 170 μrad, respectively. The viewing band is 185 km, and its periodicity is 14 days (Landsat-4). About 60 photographs taken by the MSS radiometer can be transmitted through a relay satellite in a day, with the figure for the TM radiometer being 25-30.

The Landsat satellites are launched by a Thor-Delta 3920 launch vehicle into circular orbits with an inclination of 90°. The time of active existence of the Landsat-1 and -2 was 4.5 and 5.5 years, respectively, whereas the calulated time for the Landsat-4 is about 3 years.

In the Western press it has been mentioned that by being launched into a low orbit, the Landsat--as is the case with military intelligence KA's--will be able to provide geographic resolution of up to 6 m, and that the presence on board the satellite of multichannel observation devices will make it possible to obtain additional information about surveyed objects and situations through the use of spectral analysis methods.

Work on the creation of the LRSS is now in the initial stage. The spacecraft in this system are supposed to be equipped with a TM radiometer and the new MRS model, which should provide geographic resolution of at least 15 m in the visible wave band from an altitude of 700 km. The width of the MRS radiometer's observation band will be 15 km. In connection with this, sections to be observed can be selected within limits of +50° to the side of the orbital track and +30° ahead of or behind the point beneath the satellite.

Spacecraft for radio surveillance and intercepts belong to three departments: the Air Force (the Ferret KA and those built under the 711 program), the VMS [Navy] (the NOSS [Navy Ocean Surveillance Satellite] and SSU [Sub Satellite Unit], which were developed as part of the "White Cloud" program) and the CIA (the Rhyolite and Chalet KA's).

The Ferret-D is used to conduct detailed radio and radio-engineering surveillance (RTR). In practice, it has been used since 1973 to record the characteristics of radio-engineering facilities detected previously by means of RTR or some other method. Judging from reports in the foreign press, the information gathered by it is used primarily for the development of communications-electronics combat equipment and methods. Other surveillance assignments are carried out at the same time, such as detecting the PVO [air defense] system and relocations of troops and weapons systems. In the latter case, RTR is carried out in close interaction with visual surveillance, about which the American press has written repeatedly.

The Ferret-D KA is launched by a Titan-3D rocket, as an additional load during the launching of the Lasp craft (until 1971 these satellites were launched along with Samos KA's). The working version of the Ferret-D now in use has

been used since 1966, with a total of about 40 having been launched. The Ferret-D weighs about 80 kg, and a typical orbit has an altitude on the order of 500 km and an inclination of 96.5°.

Spacecraft created under the 711 program have been launched since the beginning of the 1970's by Titan-3B launch vehicles, into elliptical orbits with a high degree of eccentricity (altitude at perigee--about 500 km; at apogee--39,000 km; inclination--63°).

The NOSS and SSU satellites are used to observe the situation on the world ocean and to detect and identify the nationality of foreign ships. Since 1976, a total of five groups of these craft (each consisting of one NOSS and three SSU's) have been launched.

These KA's are launched and used in groups in which the NOSS plays the role of the master satellite. It is heavier than an SSU and is equipped with facilities for receiving, processing and transmitting information obtained from the auxiliary SSU craft. Its data-collection facilities consist of RTR and radio-intercept equipment, and the location of ships is determined by taking bearings on the radio equipment in operation on them. The SSU satellites also carry infrared and microwave radiometers. These craft are launched by Atlas-F launch vehicles, into almost circular orbits at an altitude of about 1,100 km and with an inclination of 63.5°.

The Rhyolite and Chalet satellites belong to the CIA, although the Air Force is responsible for their technical operation. The Rhyolite KA is used to intercept telemetric information from ballistic missiles, test launches of which are conducted by other countries. The basic assignment of the Chalet craft is radio and radio-engineering surveillance.

According to reports in the foreign press, three Rhyolite KA's and one Chalet were launched into stationary and synchronous orbits in the period 1973-1979. They were launched by Atlas-Agena and Titan-3C launch vehicles, respectively.

The foreign press lists the following KA's as being under development and in the concept formation stage.

The spacecraft being created under the 980 program was previously given the provisional name of Aquacade. It is intended to be used for radio-engineering surveillance and the interception of radio reports from a stationary orbit. The program for its creation was begun in 1977 and, in the opinion of Western specialists, is now in the completion stage. It is assumed that this KA will operate in the mode of direct relay of intercepted signals. Its receiving antenna will be about 20 m in diameter. The first launch of an Aquacade KA into orbit was to take place in 1983, using the "Shuttle" ship or a Titan-3D launch vehicle.

The ITSS (Integrated Tactical Surveillance System) spacecraft is intended for the conduct of all-weather surveillance of sea TVD's and target acquisition for Navy weapons systems. The plans are to equip this spacecraft with a complex of optical and radar equipment, with the on-board radar set being able to

detect not only ships, but also military aircraft operating in sea TVD's. Work on the creation of this KA is in the initial stages. In 1981 there was an investigation of the possibility of using it for target acquisition from an equatorial orbit at an altitude on the order of 1,000 km. A decision on the full-scale development of the ITSS system is expected in 1984, and its entry into the arsenal is planned for the end of the 1980's. It has been reported that the cost of the development of this KA may be $430 million, and that the realization of the entire program, including the operation and improvement phase will cost several billion dollars.

Spacecraft that can be given the assignment of tactical surveillance of land TVD's are in the concept development stage. In particular, the following two variants for the construction of a system for tactical surveillance from space have been discussed: a so-called mixed system, in which KA's are used for strategic and tactical surveillance, with priority being given to the first, and a purely tactical surveillance system--ISTA (Intelligence Surveillance and Target Acquisition)--with the assignments of conducting observations of regions of military activity in the interests of tactical commands and for target acquisition for weapons systems.

The observation facilities being planned for these spacecraft are radar with a synthesized aperture and optical equipment operating in the infrared band, although the use of optical equipment operating in the visible band has not been eliminated. In the foreign press it has been mentioned that some delay in the creation of a KA to carry out tactical surveillance assignments has been caused by a delay in the program for the development of the large-scale designs, which should facilitate the creation of equipment for observations for tactical purposes.

In addition to the equipment listed above, the Pentagon is making active use of the manned "Shuttle" spacecraft for intelligence purposes. During a flight those ships combine the performance of intelligence assignments with transport operations, for which purpose surveillance equipment is installed in them as an additional load, and they are also fitted with the appropriate equipment in order to carry out special surveillance mission (two or three per year).

The scope of the work being done in the United States for the militarization of near space indicates the aggressive nature of its space doctrine, which is stimulating above all the development of military space facilities, with particular emphasis on surveillance means. The latter, in the opinion of Pentagon strategists, are being called on to support primarily the combat use of strategic nuclear missiles and the global use of land and sea forces.

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SOVIET DELEGATION LEADERS ON COSPAS-SARSAT PROGRAM

Moscow PRAVDA in Russian 4 Feb 85 p 7

[Article by Yu. Zurabov, director, USSR delegration to COSPAS-SARSAT international coordination group, and A. Selivanov, technical director, Soviet part of the COSPAS-SARSAT program: "Occupation of a Satellite: Rescuer"]

[Text] A world space system to search for ships and aircraft (COSPAS-SARSAT) which have experienced mishaps has been established through the joint efforts of specialists from the USSR, United States, Canada and France. It has already assisted in rescuing more than 350 persons -- citizens of different countries.

Work under this program was initiated primarily in the interests of seamen and airmen. The world merchant fleet now numbers about 75,000 ships, plus several million small fishing boats and sailboats and yachts. World civil aviation has more than 250,000 aircraft, including small private aircraft. Statistics indicate that each year 280 major ships sink. Ships of small tonnage suffer still more mishaps. In addition, scientific and research expeditions, as well as groups of tourists making journeys to remote regions, can be users of such a system.

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A timely notification is of exceptionally great importance for the rescue of people who have experienced misfortune as a result of sea and aviation disasters. It is dependent to a great extent on the effectiveness and reliability of radio communication.

The principal requirements imposed on the communication system in the event of a misfortune are: globality and the speed of its operation and highly precise automatic determination of the coordinates of the location of the mishap. All these requirements are satisfied to the highest degree by the international satellite system established within the framework of cooperation among four countries, which consists of two independent but mutually interacting parts, COSPAS and SARSAT, technically compatible with one another. The first was developed by specialists of the USSR, whereas the second was organized through the efforts of the United States, Canada and France. An international coordination group is in charge of coordination of work on the organization, maintenance and development of the system.

The COSPAS-SARSAT system is organized on the following principle: emergency radio buoys are carried by ships and aircraft and in the case of an emergency are manually or automatically activated. Artificial earth satellites receive signals from the emergency radio buoys during transit over the region of the mishap and transmit them to data reception points. There the signals are automatically processed for determining the coordinates of the accident.

Over the course of several years the scientists and specialists of the four countries did much in the development and production of extremely complex satellite and surface instrumentation, in organizing centers for the system and perfecting their interaction and in developing program software support for the computer complexes at the centers and at the data reception points. After completion of this work, in June 1982 the Soviet Union launched the first satellite in this system ("Cosmos-1383") and began flight tests under the joint program. The second Soviet satellite, "Cosmos-1447," and the first American satellite, NOAA-E, were launched in March 1983. Three Soviet satellites are now functioning in orbit. In December of last year a second American satellite was launched to replace the first, which failed in June 1984.

The experimental stage, intended for demonstrating and evaluating the possibilities of the system, continuing more than two years, confirmed the correctness of the technical solutions and the total compatibility of the elements and parts of the system developed in different countries. These tests were carried out in different regions of the world, in particular, using merchant ships making voyages from ports of the USSR to Antarctica. Similar tests were made by other countries in accordance with a jointly agreed-upon program. A high reliability and effectiveness of the Soviet satellites, by means of which a high percentage of all the rescue operations was effectuated, were noted repeatedly.

Ground data reception centers have now already been established in the countries which developed the system: USSR, United States, Canada and France; an exchange of information among them was organized. The successful course of demonstration and evaluation of the system, in the course of which so many human lives were saved, drew the attention of other countries and international maritime and aviation organizations. Great Britain and Norway constructed and successfully tested their own data reception points on their own initiative. Bulgaria and Finland have undertaken experimental work. Denmark and Brazil have made overtures for participation in the system. New Zealand, Spain, Australia, Sweden and a number of other countries have shown great interest in this work.

The most recent session of the COSPAS-SARSAT coordination group, which was held late last year in Leningrad, was of fundamental importance for the further development of the system. The unanimous conclusion was drawn that the stage of demonstration and evaluation of the system had been successfully completed and that it was ready for an experimental operation regime. The changeover to this qualitatively new stage in the development and use of the system was reflected in a document on the continuation of cooperation signed by representatives the USSR Ministry of the Maritime Fleet, United States

NOAA, Canadian Defense Ministry and French National Space Research Center.

The changeover of the COSPAS-SARSAT system to an experimental operation regime requires a further improvement in the space and surface elements of the system. For this purpose the participating countries have assumed the obligation of maintaining not less than four satellites in orbit at all times.

A reliable basis is being created for technical improvement of system elements within the framework of the established and agreed-upon structure. Provision has been made in all countries for mastery of mass production of radio buoys of a new type, making more effective use of the possibilities of the satellite system.

The successful international cooperation in the COSPAS-SARSAT system is indicative of the possibility and necessity of bringing together the efforts of different countries in the use of space exclusively for peaceful purposes.

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